

# The Role of Shadow Banking in the Monetary Transmission Mechanism

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*To Dagmar, Waldo, Eric and Nicole.*



## ABSTRACT

This thesis consists of three essays that analyze the reaction of financial institutions to monetary policy. In the first essay, I use a Bayesian VAR to show that an increase in the monetary policy rate raises credit intermediation by non-bank financial institutions (NBFI). As is well known, credit intermediation by banks is reduced. The movement in opposite directions is explained by the difference in funding. This finding suggests that the existence of NBFI may decrease aggregate volatility following monetary policy shocks.

Following this evidence, I construct a theoretical model that includes different types of funding in the second essay. Households face a savings choice between state contingent (equity) and non-state contingent (debt) assets. I use the financial accelerator model of Bernanke, Gertler and Gilchrist (1999) as a basis and microfound the decision by which new net worth in entrepreneurs is created. A Bayesian estimation suggests a change in the survival rate of entrepreneurs, affecting impulse responses. The analysis suggests that models that use the financial accelerator should include endogenous firm entry if variables regarding household portfolios or shocks directly affecting firm net worth are considered.

In the third essay, I develop an estimated monetary DSGE model with funding market frictions that is able to replicate the empirical facts. In a counterfactual exercise I study how the regulation of shadow banks affects an economy at the ZLB. Consumption volatility is reduced when shadow bank assets are directly held by commercial banks. Alternatively, regulating shadow banks like investment funds results in a milder recession during, and a quicker escape from, the ZLB. The reason is that a recessionary demand shock that moves the economy to the ZLB has similar effects to a monetary tightening due to the inability to reduce the policy rate below zero.

**Keywords:** Shadow banking, monetary policy, credit supply, Bayesian VAR, Bayesian estimation, zero lower bound, search frictions.



## ZUSAMMENFASSUNG

Diese Doktorarbeit besteht aus drei Aufsätzen, in welchen die Reaktion von Finanzinstitutionen auf Geldpolitik analysiert wird. In dem ersten Aufsatz finde ich anhand eines Bayesian VAR, dass eine Erhöhung des Leitzinses zu einer zusätzlichen Kreditvergabe in Nichtbanken (NBFI) führt. Banken verleihen wie bereits bekannt weniger. Der Grund für die gegensätzliche Bewegung liegt in der unterschiedlichen Art der Finanzierung. Dieser Befund legt nahe, dass die Existenz von NBFI die Volatilität der aggregierten Kreditvergabe zu geldpolitischen Schocks verringern könnte. Zusätzlich bietet die Analyse einen Erklärungsansatz für die Beobachtung, dass sich die Kreditvergabe seit der Finanzkrise stockend entwickelt hat.

Im zweiten Aufsatz knüpfe ich an diese empirische Untersuchung an, indem ich ein theoretisches Modell mit unterschiedlichen Arten von Firmenfinanzierung entwerfe. Haushalte müssen sich zwischen festverzinslichen und erfolgsbedingten Sparmöglichkeiten entscheiden. Auf Grundlage des Modells von Bernanke, Gertler und Gilchrist (1999) mikrofundiere ich die Entscheidung über Unternehmensgründung in Form von Eigenkapitalinvestitionen.

Im dritten Aufsatz entwickle ich ein geschätztes DSGE Modell mit Finanzierungsfriktionen, welches in der Lage ist, die empirischen Ergebnisse zu replizieren. Ich untersuche, wie sich die Regulierung von Schattenbanken auf eine Volkswirtschaft am ZLB auswirkt. Konsumvolatilität wird reduziert, wenn Schattenbankenkredite stattdessen von Banken vergeben werden. Alternativ dazu führt die Behandlung von Schattenbanken wie Investment Fonds dazu, dass eine Volkswirtschaft am ZLB eine mildere Rezession und einen schnelleren Austritt erlebt. Der Grund liegt darin, dass ein Nachfrageschock, der die Volkswirtschaft zum ZLB bringt, eine Reaktion hervorruft, die vergleichbar mit geldpolitischen Schocks ist, da am ZLB keine Möglichkeit der Leitzinsverringerung besteht.





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My dad has contributed most to my interest in the discipline and its application to the real world. His fascination with the interaction of economics, politics and society has been a huge resource for my own drive to understand the world in more detail. In addition, he has supported me with the most valuable resource: spending his time to provide feedback on my ideas, expositions and writing.

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## INTRODUCTION

Monetary policy affects the economy via different channels (Boivin et al., 2010). The credit channel concerns the ability of a central bank to influence the real economy via credit intermediation (Bernanke and Gertler, 1995) and has been extensively studied in the past several decades (Peek and Rosengren, 2013). Among many other findings in that literature, the heterogeneous effects of monetary policy are notable: credit intermediation is affected differently for creditors of different sizes (Kashyap and Stein, 1995), legal structures (Campello et al., 2002; Gambacorta, 2005), funding sources (Kashyap and Stein, 2000; Cetorelli and Goldberg, 2012), etc.; just as debtors react differently depending on size (Gertler and Gilchrist, 1994), industries (Dedola and Lippi, 2005), liability compositions (Kashyap et al., 1993), etc. Since credit is now intermediated to a large extent by shadow banks, there is reason to believe that such credit may react to monetary policy in ways that are different from bank credit.

The term shadow banking was coined by McCulley (2007) to loosely refer to credit intermediation by non-bank financial institutions (NBFI) – a part of the financial economy that had been funding both the real economy (especially housing) and other financial institutions. This vague definition is best characterized by the exclusion of entities that have explicit access to a lender of last resort and that fund themselves via deposits, i.e., commercial banks. NBFI are differently regulated from commercial banks and may therefore be underregulated by supervisory institutions and also escape being included within the credit economy. In fact, according to some estimates the shadow banking system in the United States grew to exceed the commercial banking system prior to the financial crisis (see e.g., Pozsar, 2013).

There is no single agreed upon definition for what constitutes shadow banking. Depending on the application, shadow banking may be defined as the sum of all entities that engage in credit intermediation without being regulated like commercial banks (Pozsar et al., 2010), the value of activities that are exposed to certain risks not covered by traditional regulation (Financial Stability Board, 2015), institutions that rely on a public or private backstop (Adrian and Ashcraft, 2012; Claessens and Ratnovski, 2014), credit that is prone to runs (Gallin, 2013),

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or any number of such alternative characteristics.

The reaction of credit intermediation by NBFIs to monetary policy is the focus of my empirical analysis in the next chapter. Since institutional characteristics matter, I include commercial banks and split NBFIs into two different groups based on their liability characteristics and relationship to the rest of the economy. The first group, shadow banks, includes highly leveraged institutions that mostly depend on funding from other financial institutions. The second group, investment funds, consists of institutions that are directly accessible to households and that receive funding in the form of equity investments instead of debt. I find that all these groups' credit intermediations differ in their reaction to monetary policy: While banks decrease lending following an increase in the policy rate set by the central banks, both shadow banks and investment funds increase lending. The reaction of NBFIs stands in contrast to the traditional understanding of the credit channel and is mostly due to different kinds of funding into these institutions by their creditors.

The ability of financial institutions to provide credit is in part governed by the bank lending channel, which posits that a higher policy rate results in less reservable deposits available to deposit-taking institutions. This is due to the open market operations of the central bank, which, in the process of increasing the policy rate, eliminates reserves that are necessary to satisfy reserve requirements. Banks can offer non-deposit liabilities or raise equity, but since neither is a perfect substitute for deposits, banks will have to reduce lending. Investment funds that fully finance their operations via equity are not affected by this channel. Because high interest rates incentivize savers to search for high-yielding assets, by adjusting creditor compensation, investment funds can increase their funding, which results in an increase in lending. Investment funds are able to do this, because their return on lending normally increases, which they can pass on to their investors as equity returns. The increase in shadow bank lending is likely due to banks channeling more resources via off-balance sheet institutions that they own and control, which is a form of regulatory arbitrage. However, I am unable to fully determine these channels in the context of my empirical strategy. To explore these empirical results further, I turn to a theoretical approach.

The incorporation of financial frictions into theoretical models was a dominant theme in the 1990s (Blanchard, 2000), but was not considered a core feature in the models of the new neoclassical synthesis that combined new classical and new Keynesian macroeconomics (Woodford, 2009). The literature on financial frictions

again flourished during the global financial crisis and has maintained a prominent status since then. Financial frictions can be modeled implicitly via inefficiencies or explicitly by including an agent that represents the financial sector. Many models with dedicated banking sectors exist (Guerrieri et al., 2015), some of which allow consideration of more than one financial entity (e.g., Verona et al., 2013). I am interested in modeling the behavior of three distinct types of financial entities, since they all differ institutionally and behave in different ways empirically as is shown in the first chapter. In addition, current regulatory proposals are likely to affect these three groups in different ways, necessitating finer granularity.

One of the major distinctions I propose is the reliance of investment funds on equity. Most existing models, however, feature financial institutions that rely mostly or solely on debt finance, as is indeed the case for banks and similar institutions. Although the selected framework, the model with financial frictions of Bernanke et al. (1999), features an institution that leverages up its liabilities, the equity portion of the balance sheet is not determined by the agents. This ignores optimizing behavior and reactions to shocks, which could well matter for macroeconomic dynamics. The incorporation and analysis of equity financing in the workhorse model of Bernanke et al. (1999) is the focus of the third chapter. This distinction matters, since the monetary transmission mechanism operates differently via the liability components of the intermediaries.

In the fourth chapter I incorporate the three financial institutions as distinct agents into a monetary DSGE model by using the theoretical extension developed in chapter three. I contrast the behavior of the model economy from that of Gertler and Karadi (2011), a model that features only one aggregate financial sector, which ignores the sectoral heterogeneity. If we consider an economy during normal times, the effects of the same monetary policy shock are comparable across models, although aggregate credit intermediation with NBFIs is muted compared to Gertler and Karadi (2011). By adjusting parameters that govern the elasticities of credit intermediation to monetary policy shocks, one could incorporate only one large financial system that ignores the sectoral heterogeneity, but corresponds to my empirical results.

This result does not hold anymore if the economy is at a demand-induced Zero Lower Bound (ZLB). Nominal interest rates, which are the basis of credit remuneration (including deposits), cannot go much below zero and therefore cannot induce additional consumption, investment and dissavings. Equity returns, on the other hand, are generally higher than credit returns (Mehra and Prescott, 1985)

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and can therefore decrease for a longer period, eliciting spending even when net nominal rates are bound by zero. Allowing for the heterogeneity then becomes crucial, as lenders funded by equity continue to stimulate aggregate credit as well as the economy, while debt-funded lenders do not. Consequently, having a financial system that is regulated to facilitate equity funding of intermediaries over debt funding is helpful when an economy is at the ZLB. This key result is explained in the final chapter.

## THE REACTION OF FINANCIAL INSTITUTIONS TO MONETARY POLICY SHOCKS – AN EMPIRICAL EXPLORATION

How do different types of financial institutions respond to changes in the monetary policy rate? Counter to the credit channel of monetary transmission, I show in a Bayesian Vector Autoregression that an increase in the monetary policy rate of 100 basis points raises credit intermediation by two different types of non-bank financial institutions (NBFI): investment funds increase lending by 4 percent and shadow banks increase lending by 1 percent. Credit intermediation by banks is reduced by about 0.5 percent. The movement in opposite directions is explained by the difference in funding between banks and NBFI. This finding suggests that the existence of NBFI may decrease aggregate volatility following monetary policy shocks. In addition, it offers an explanation for why lending since the financial crisis has been sluggish and suggests potential options for relief in case the lower bound on monetary policy is binding.

## 2.1 Introduction

The credit channel posits that following monetary tightening the amount of credit in an economy is reduced, which amplifies traditional interest rate and asset price channels. However, while empirical studies find that banks decrease lending, non-bank financial institutions (NBFI) increase credit intermediation.<sup>1</sup> In the past decades, the share of real economy credit intermediated by NBFI has grown substantially, even overtaking the traditional commercial banking sector in several countries, see Financial Stability Board (2014). In this paper, I explore how and why different financial institutions react differently to monetary policy tightening. For this purpose, I estimate a Bayesian Vector Autoregression (BVAR) that includes variables for volumes and prices of different credit markets, which allows me to assess the relevance of supply and demand factors.

One part of the credit channel is the bank lending channel. It posits that the amount of loanable funds available to banks will decrease after monetary policy tightening, because of an outflow in deposit funding. If banks can substitute into non-deposit funding, the bank lending channel is weakened (Kashyap and Stein, 1995). In a related sense, if the real sector can substitute non-bank funding for bank credit, policy tightening would not have as large an effect on aggregate credit supply (Gertler and Gilchrist, 1994). Because the supply schedule of bank lending cannot be observed, an alternative argument can be made that the demand schedule is moved inwards after monetary tightening, because potential borrowers anticipate a weaker economy and postpone debt-funded consumption and investment. In the following, I try to disentangle the supply and demand factors. This will also allow me to make suggestions about what financial institutions are less inhibited by the zero lower bound on monetary policy.

The remainder of the paper is structured as follows. In the next section, I will explain my data sources. Section 3 contains the specification of the VAR and identification of monetary policy shocks, as well as my results and a comparison to the literature. I explore robustness of my specification in Section 4 and conclude in Section 5.

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<sup>1</sup>See e.g., Pescatori and Sole (2016); Nelson et al. (2015); Igan et al. (2013); den Haan and Sterk (2011); Altunbas et al. (2009).

## 2.2 Data

Data from the real economy include GDP, the CPI, an index of sensitive commodity prices, money stock M2, total central bank reserves and non-borrowed reserves as in Christiano et al. (1999).<sup>2</sup> The data are from Stock and Watson (2012). Data on GDP is available quarterly, while the other variables are measured in a higher frequency. For the baseline specification, I will use data from 1960 to 2006. I do not use data after 2006, because the zero lower bound on monetary policy was binding, which complicates the identification of monetary policy shocks. Also, the financial crisis likely resulted in a change in regulation and perception of the financial industry, which could introduce structural breaks in the parameters. A structural break in the conduct of monetary policy between the pre- and post-Volcker chairmanship of the Federal Reserve is often argued, see Clarida et al. (2000). I will therefore conduct a robustness analysis for my baseline specification in Section 2.5.1.

Data for the financial sector variables are from the Financial Accounts of the United States, which offer sectoral data on different types of lending. In this paper I define shadow banks as intermediaries that are active in markets with securitized assets and that are generally funded by other institutional investors and banks. In this specification, they are ABS Issuers, Security Brokers and Dealers, Financing Companies and Funding Corporations. Investment funds are open ended funds that issue and redeem fund shares directly, instead of having their shares traded in a market. They are generally accessible by households. Open ended funds are Mutual Funds and Money Market Funds. Banks take deposits from households and originate loans directly. They are U.S. Depository Institutions and Credit Unions.

In the baseline specification I include loans, bonds, consumer credit and commercial paper as a measure of credit. Intermediaries typically fund substantial amounts of securities issued by the government and municipalities, as well as asset-backed securities (ABS) backed by government-sponsored entities (GSE). I purposely exclude these items in the measure of real economy credit since securities with implicit or explicit government guarantees are often assumed for liquidity reasons and to be used as collateral; and may therefore serve a different purpose than to profit from lending. I will include these items in one specification to illuminate their general behavior and to allow comparisons with the literature.

To understand whether changes in lending are demand or supply driven, I take

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<sup>2</sup>For a list of data sources and definitions, see Table A.1 in the Appendix.

the baseline specification and add data on interest rates one at a time, following the marginal approach by Christiano et al. (1996) and Kim (2001). Bank borrowing rates are proxied by the prime lending rate from the FRED database. Investment fund interest rates are proxied by investment fund returns, which are the averages of total returns per share weighted by the equity of each fund. Data are taken from the CRSP database and are available monthly.

In order to explore the reason behind the opposing directions of different types of intermediaries, I will include variables on intermediary funding. Banks offer checkable deposits as well as time and savings deposits. Investment funds offer money market fund shares and mutual fund shares. Households are generally not able to directly fund shadow banks.

The availability of sectoral balance sheet data dictates an analysis at the quarterly frequency. All USD-denominated variables have been transformed into logs and are included in the BVAR in levels. Intermediary credit has been deflated using the CPI. Interest rates are not transformed.

## 2.3 Empirical strategy

### 2.3.1 Vector Autoregression

As explained in Christiano et al. (1999) and Ramey (2016), the data can be described by a multivariate vector autoregression of the form

$$Z_t = B_1 Z_{t-1} + B_2 Z_{t-2} + \dots + B_q Z_{t-q} + u_t. \quad (2.1)$$

The  $k$ -dimensional vector of variables  $Z_t$  can be described by lagged variables of order  $q$  with matrices of coefficients  $B_i$  ( $i \in 1, \dots, q$ ). The differences between the actual realizations of  $Z_t$  and the predicted values on the right-hand side of Equation 2.1 are the one-step ahead forecast errors  $u_t$ , which are uncorrelated with past variables. Forecast errors capture all of the unexpected movements in the variables due to fundamental shocks. However, each element of  $u_t$  summarizes the contemporaneous effects of all fundamental shocks on the corresponding element of  $Z_t$ .

The purpose of this study is to identify fundamental shocks in the form of monetary policy shocks. I assume that the forecast errors  $u_t$  are a linear combination of fundamental shocks  $\varepsilon_t$  with the relationship expressed by



$$A_0 u_t = \varepsilon_t.$$

Premultiplying the reduced-form VAR system in Equation 2.1 with the matrix  $A_0$  transforms it into a structural VAR of the form

$$A_0 Z_t = A_1 Z_{t-1} + A_2 Z_{t-2} + \dots + A_q Z_{t-q} + \varepsilon_t, \quad (2.2)$$

with  $A_i = A_0 B_i$ . The matrix  $A_0$  can be found by assuming that the monetary authority's decision making is based on an information set  $\Omega_t$  and shocks are orthogonal to this set.

### 2.3.2 Identification via the recursiveness assumption

The baseline analysis concerns the reaction of real sector lending by intermediaries to monetary policy shocks. I follow Christiano et al. (1999) in the selection of variables and the identification of shocks by assuming that the monetary policy makers choose their target for the federal funds rate based on their information set  $\Omega_t$ . Variables contained in  $\Omega_t$  are contemporaneous measures for GDP, the CPI and the index of sensitive commodity prices. These variables are captured in the vector  $X_{1t}$ . The remaining variables are M2 money stock, total reserves, non-borrowed reserves and the amount of lending for each intermediary, which make up the vector  $X_{2t}$ . Policymakers observe the second set of variables only with a lag of one period.

Assuming the vector of variables  $Z_t$  is constructed as  $Z_t = (X'_{1t}, S_t, X'_{2t})'$  with  $S_t$  being the monetary policy variable, I can incorporate the timing assumptions into the information set by setting the block matrix  $A_0$  to

$$A_0 = \begin{bmatrix} a_{11} & 0 & 0 \\ a_{21} & a_{22} & 0 \\ a_{31} & a_{32} & a_{33} \end{bmatrix}. \quad (2.3)$$

Variables in the first block of  $Z_t$  are only affected by fundamental shocks in  $X_{1t}$ . Because they are slow moving, they do not respond to contemporary shocks of the remaining variables in  $Z_t$ . This is captured by the  $3 \times 3$  matrix  $a_{11}$  and the zero restrictions on the remaining variables in the first row of matrix  $A_0$ . Monetary policy does react to shocks to the first block, captured by  $a_{21}$ . It cannot react to the

second block  $X_{2t}$ , which necessitates zero restrictions on the remaining variables. Fast moving variables in  $X_{2t}$  potentially respond to all shocks. Since I am only interested in the effects of monetary policy shocks, the ordering of variables within their blocks does not matter.

I use the Federal Funds Rate (FFR) as a proxy for monetary policy. In the baseline setup, the variables in the second block can respond contemporaneously to monetary policy shocks. The argument can be made that intermediaries take time to analyze and respond to changes in monetary policy. In that case, they should be ordered in the first block of variables before the FFR. In order to explore the robustness of my baseline assumption, I will transfer intermediary balance sheets into the first block in Section 2.5.2. I use a lag order of 4 to capture the dynamic properties of the quarterly data set.

Because of the large number of parameters resulting from the many variables and lags chosen, I adopt an estimation approach with Bayesian shrinkage of VAR parameters as in Koop and Korobilis (2010) and Banbura et al. (2010). I report the percentage change of variables in the impulse response functions compared to the unshocked path. I include confidence intervals at the 68 percent and 95 percent level.

## 2.4 Results

### 2.4.1 The reaction of intermediary lending to monetary innovations

The first exercise concerns the general adequacy of the identification to capture monetary policy shocks. I take the maximum amount of data (1960I:2006IV) and consider the reaction of all variables used by Christiano et al. (1999) and all assets (real and public sector credit as well as equity holdings) of the three intermediaries in response to a monetary tightening in Figure 2.1. After an increase in the FFR of 100bp, GDP falls in a hump-shaped way to a maximum of about minus 0.6 percent after two years. The CPI exhibits the price puzzle: it increases initially, before it falls after about 10 quarters. The index of commodity prices exhibits a quicker reaction and falls after about four quarters. Non-borrowed reserves fall, while total reserves stay constant initially. This suggests that the monetary authority increases borrowed reserves to insulate the drop in total reserves, as argued by Christiano et al. (1999). These results are all in line with the established literature.

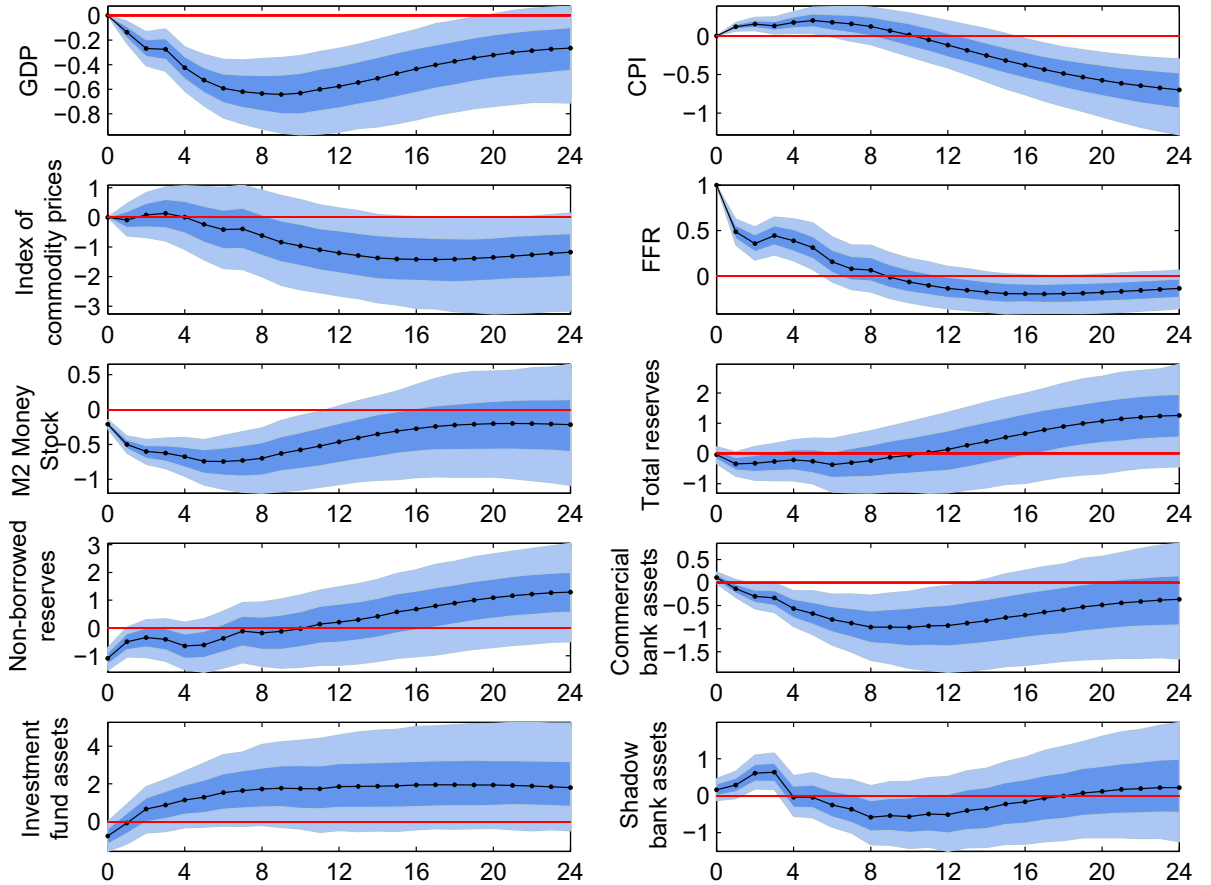


Figure 2.1: Responses of intermediary assets to a contractionary monetary policy shock. *Note: Shaded regions are the 32-68th and 5-95th percentage confidence regions.*

Banks decrease their balance sheets in a hump-shaped manner to a negative one percent after about eight periods. In the very first period, their balance sheets increase slightly, which may be attributable to an increase in borrowing by bank clients with pre-established credit lines. These loans made under commitment increase after tightening, because borrowers anticipate an increase in the cost of obtaining credit elsewhere (Morgan, 1998). Shadow banks initially increase their balance sheets by about 0.6 percent during the first year, before they decrease their assets in years two to four. Investment funds increase their assets persistently by about 1.8 percent starting three quarters after the shock.

The reaction of investment funds to monetary policy becomes more clear when we focus on fixed income assets to the private sector, instead of considering the whole balance sheet. Figure 2.2 shows the results of what I call the baseline specification for the remainder of the analysis. After a 100bp increase in the FFR, investment funds increase their fixed income holdings quickly by about 4 percent.

Intermediation stays elevated for about two years, before it slowly drops to the unshocked path around 16 quarters after the shock. Banks do not decrease fixed income credit as quickly, which might be due to an increase in loans under commitment, as argued above (Morgan, 1998). Fixed income credit held by shadow banks increases by one percent.

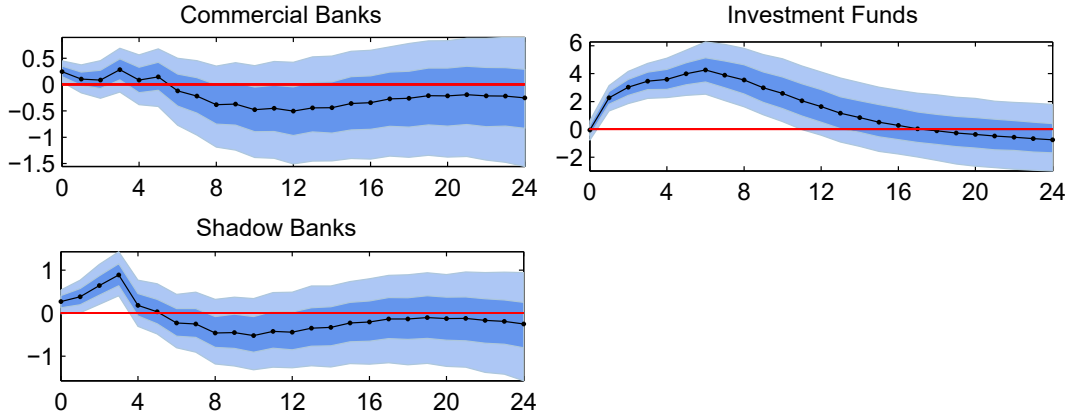


Figure 2.2: Responses of fixed income credit holdings by intermediaries to a contractionary monetary policy shock. *Note: This is the baseline specification. The full BVAR is available in the Appendix, Figure A.1.*

Table 2.1 shows the forecast error variance decompositions of some key variables to monetary policy shocks. The results are broadly comparable with the literature, however output variance is less affected in this analysis, while CPI is more affected than in Christiano et al. (1999). The difference might be due to the larger data sample used here (1960Q1:2006Q4 versus 1965Q3:1995Q2) or due to the difference in estimation via Bayesian priors. Interestingly, monetary policy shocks can explain a much larger share of the variance of investment fund lending than lending by commercial banks and shadow banks. The higher sensitivity might be due to operations of investment funds being more focused on credit intermediation and similar investment operations. This compares to the much broader services commercial banks offer, which might allow them to cross subsidize credit operations. Another plausible stabilizer is bank funding in the form of deposits, which are less interest sensitive because they are used for reasons other than savings. This understanding is more difficult to reconcile with shadow banks, which are narrowly focused. Being owned and controlled by bank holding companies would also speak for a similar type of cross subsidization.

Horizon	2	4	8	12	16	20
GDP	2	6	21	28	29	29
CPI	3	4	3	2	3	8
FFR	73	45	32	29	29	29
Commercial bank lending	2	1	1	2	2	2
Investment fund lending	11	24	29	28	26	24
Shadow bank lending	3	8	4	4	4	3

Table 2.1: Variance decomposition for key variables – share of variance explained by monetary policy shocks, 1960Q1 to 2006Q4 (all numbers in percent).

### 2.4.2 Identifying supply and demand factors

In order to answer the question why investment funds increase lending while banks decrease lending, it is necessary to understand whether the change in credit volumes are due to the supply or the demand side: banks may reduce lending because they prefer to shrink their balance sheet, or because there is not sufficient demand from borrowers. This can be pictured in a simple supply and demand diagram. If the reduction in credit is mainly due to a reduction in credit supply, we would expect an increase in the price, or the interest rate, that borrowers have to pay (left hand side of Figure 2.3).

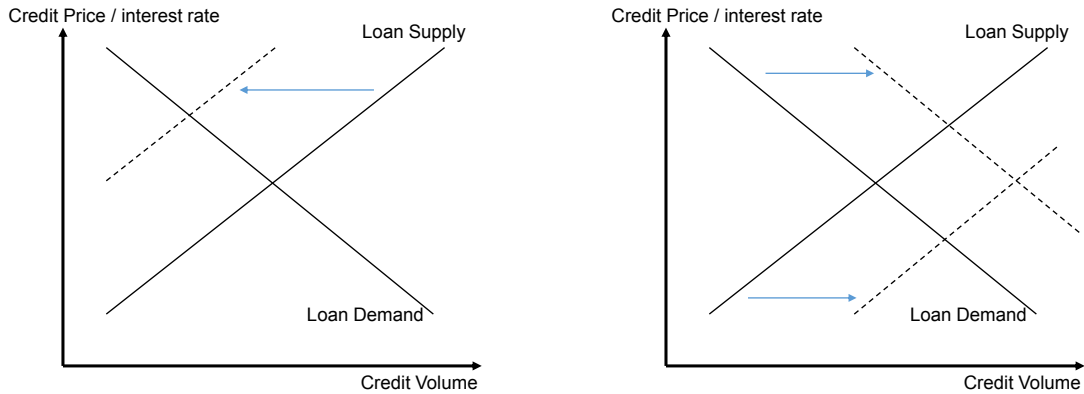


Figure 2.3: Exemplary supply and demand schedules on the credit market.

Including the price introduces new parameters that have to be estimated. Since the number of observations does not increase, the confidence bands around the impulse response function will necessarily widen. As a proxy for the interest rate that banks charge, I include the bank prime loan rate. Figure 2.4 shows that it increases by about 0.8 percent and moves in line with the FFR. Together with the initial increase in credit, this suggests that demand for bank credit initially increases (the loan demand schedule is moved outward). After five periods, the

volume drops below the baseline but the price stays elevated. That points to a reduction in the supply of credit as in the diagram.

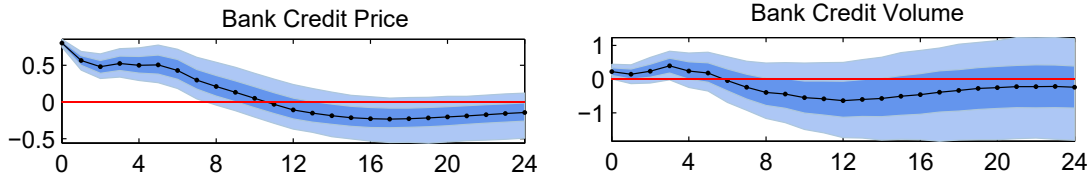


Figure 2.4: Responses of bank credit price and volume. *Note: Full BVAR is available in the Appendix, Figure A.2.*

Including the interest rate for investment fund lending allows the analysis of supply and demand factors in that market. There is no simple proxy for investment fund interest rates on the lending side. I instead take gross returns of investment funds as a proxy. In the period of the monetary tightening shock, investment fund returns drop below the baseline by a statistically significant amount, see Figure 2.5. However, the drop of 0.004 percent is not economically significant and the subsequent movement is negligible. Given the increase in investment fund credit, this result is consistent with a simultaneous increase in credit supply and demand, see the right hand side of Figure 2.3.

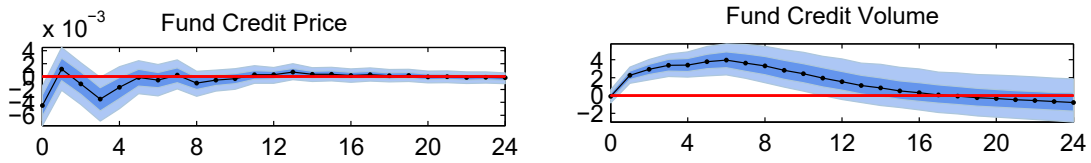


Figure 2.5: Responses of fund credit price and volume. *Note: Full BVAR is available in the Appendix, Figure A.3.*

An increase in credit demand at investment funds makes sense, given that bank credit becomes more expensive and eventually drops altogether. This could be due to some borrowers moving away from the banking sector to investment funds. Since investment fund returns stay flat, this suggests that investment fund credit supply also rises. How does this come about? In order to explain the increase in credit supply, we need to look at the funding side of credit institutions.

First, I include funding sources for banks. I differentiate between checkable deposits, small time and savings deposits, and large time deposits, because they are different savings devices from the creditors' perspective as they have different interest rates, maturities and risk profiles. Figure 2.6 shows that deposits and small time and savings account decrease for eight and six periods, respectively.

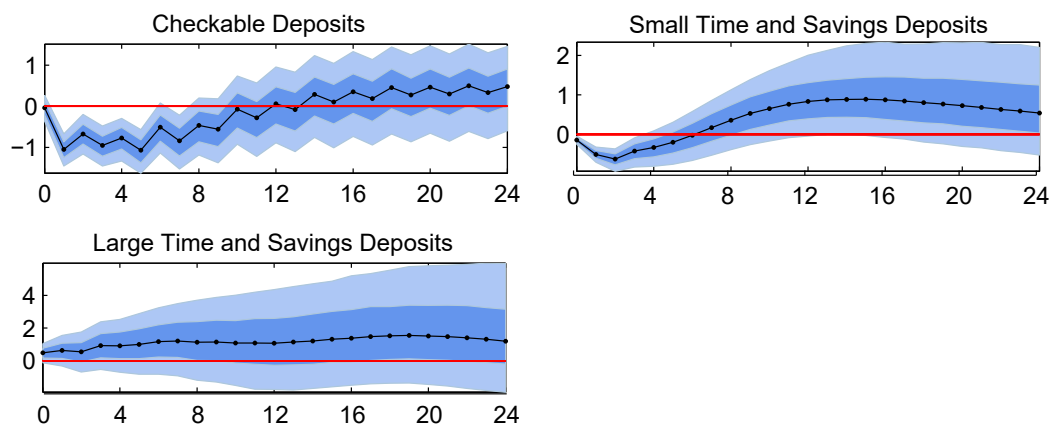


Figure 2.6: Responses of bank funding. *Note: Full BVAR is available in the Appendix, Figure A.4.*

Both increase after two to three years, before they return to the baseline. Large time deposits increase and stay elevated for several years, but not statistically significantly at the 95 percent level.

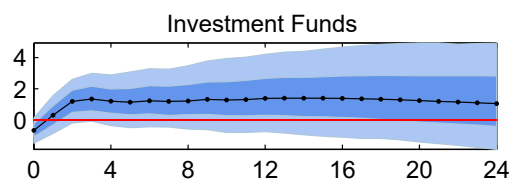


Figure 2.7: Responses of investment fund shareholdings. *Note: Full BVAR is available in the Appendix, Figure A.5.*

Shareholdings in investment funds increase, see Figure 2.7. This result corresponds with the hypothesis that investment funds do not increase lending rates after a monetary tightening, since they have more resources to conduct intermediation.

### 2.4.3 Comparison with results from the literature

Nelson et al. (2015) conduct a similar analysis of the reaction of intermediary balance sheets to monetary policy shocks, but differ in a number of important ways: They look at the change in the total size of the balance sheet instead of one asset class (fixed income holdings with the real sector as in this paper). This is an imperfect measure when one is interested in the effectiveness of the credit channel, as financial intermediaries are invested in equity as well as government and municipal debt, which are often held for collateral purposes. Secondly, they estimate their VAR in first differences, which results in an interpretation about

the asset growth instead of the change in assets. Lastly, their definition of shadow banks does not include security brokers and dealers. Nonetheless, their results are complementary to the ones in this paper: commercial bank asset growth drops after monetary tightening, while shadow bank asset growth increases.

In a Factor-Augmented VAR, Igan et al. (2013) study the effects of monetary policy shocks on intermediary balance sheets. Because of their differing methodology, they include over one hundred variables, but limit themselves to the time from 1990Q1 to 2008Q2. Regarding the variables of interest, they similarly find that one type of investment fund, money market funds, increase assets after monetary tightening. A type of shadow bank, security brokers and dealers, also increase assets. Another type of shadow bank, ABS issuers, decrease both mortgages and total liabilities, i.e., one variable that I exclude (mortgages) and another variable that is too broad for my purposes (total assets/liabilities).

Pescatori and Sole (2016) estimate a VAR with banks, ABS issuers and finance companies, but also include government sponsored entities (GSE), agency and GSE-backed mortgage pools and life insurance companies. The focus of the analysis is on GSE, which reduce own asset holdings but finance off-balance sheet assets. The authors conclude that monetary tightening decreases aggregate credit intermediation, but increases the relative sizes of non-banks, thereby potentially increasing systemic risk by pushing credit intermediation to less regulated sectors.

den Haan and Sterk (2011) analyze whether financial innovation is responsible for the Great Moderation. They estimate the response of mortgage and consumer credit held by banks and non-banks. Although they ultimately reject the hypothesis that financial innovation has led to reduced volatility in real variables, their results regarding the reaction of credit to monetary tightening corresponds with the results in this paper: Bank mortgages and consumer credit decline or stay relatively flat, respectively, after monetary policy tightening, while non-bank holdings increase. An important observation is that there is a trend break around the Volcker chairmanship of the Fed, which I take into account in the robustness analysis in Section 2.5.1.

In line with these results, Altunbas et al. (2009) show that European banks that rely more on securitization are less affected by monetary policy shocks. This result makes sense in light of the above evidence when one considers European banks to consist of a dedicated banking part and a non-bank part. A higher concentration of predominantly non-bank activities insulated the reaction of credit intermediation to monetary tightening.



## 2.5 Robustness

### 2.5.1 Shortened Time Horizon: Great Moderation

The time series literature generally agrees that there have been breaks in the trend of several macroeconomic variables over the past decades, but the exact date is not clear (Boivin et al., 2002). Following the literature, I will estimate my baseline VAR, but with a reduced data range of the time after the high inflation years of the Volcker Fed chairmanship. Starting with the year 1984 has another benefit: Regulation Q, which prohibits banks from raising deposit rates above a ceiling, was phased out in the early 1980s. Regulation Q is often understood as a driver for the development of alternative forms of savings, predominantly money market mutual funds (Gilbert, 1986).

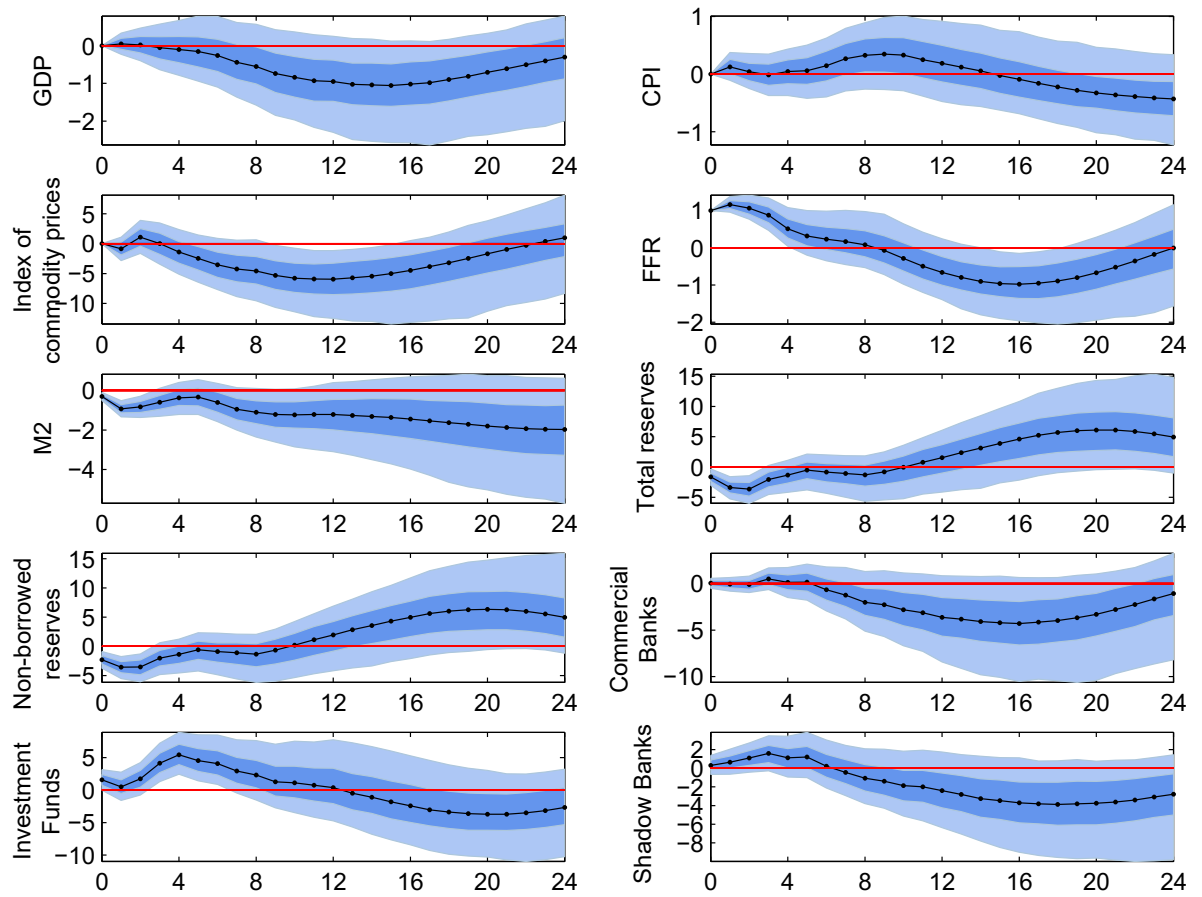


Figure 2.8: Responses of intermediaries during the Great Moderation. *Note:* Baseline specification with data from 1984I:2006IV.

Figure 2.8 shows the result for the baseline BVAR for the shortened time horizon 1984I:2006IV. The reaction of the three intermediaries is qualitatively comparable. Banks now react more strongly quantitatively to the shock: they

reduce credit by just over 4 percent. Investment funds react with more of a lag, only raising credit after three periods, but more strongly by over 5 percent. Shadow bank credit increases more strongly, too, but not statistically significantly at the 95 percent level. The reduction after seven periods is also stronger than in the longer sample.

Real variables behave broadly the same as in the longer horizon, but with a higher amplitude in response to a shock. This is probably due to the behavior of the FFR being more persistent in response to a monetary tightening. Secondly, the volatility of the monetary shocks time series in the years 1984 to 2006 is 0.39, compared to a higher volatility in the years 1960 to 1977 of 0.59, see Figure 2.9.<sup>3</sup> This corresponds with Boivin et al. (2002) and indicates that monetary policy has become more systematic in response to the data included in the VAR.<sup>4</sup>

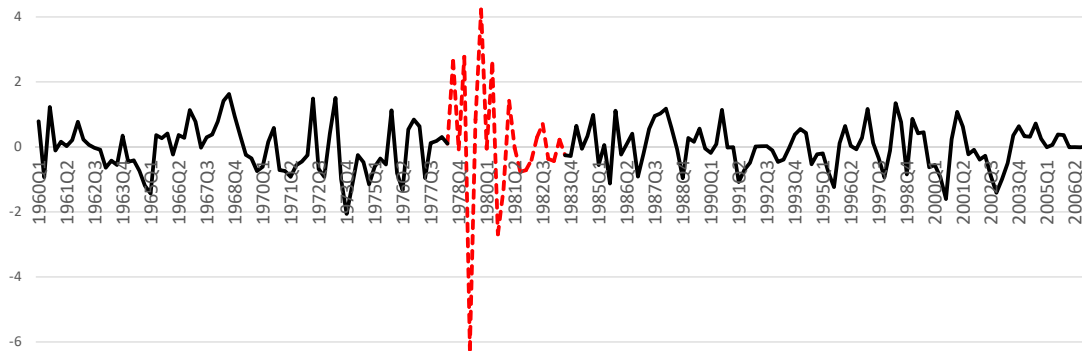


Figure 2.9: Monetary shock time series. *Note: Extracted from the baseline BVAR. The vertical axis shows units in terms of the standard deviation of the shock. The red, hatched line indicates data that is excluded in the calculation of the monetary shock volatility.*

The great moderation did not only see a reduction in the overall variance of macroeconomic variables, but also in the share that can be attributed to monetary policy shocks. This can be seen in Table 2.2, which again indicates a reduction in the unsystematic part of monetary policy. Another interesting development is that only up to a horizon of three years is lending by investment funds more strongly affected by monetary policy shocks than lending by commercial banks and shadow

<sup>3</sup>I exclude data around the high inflation period and strong interest rate intervention by Paul Volcker. Extending the time horizon until 1984 would increase the volatility of the monetary shock time series to 1.40.

<sup>4</sup>This depends on the interpretation of an empirical monetary policy shock, which can alternatively be understood as shifts in the weight given to varying goals by the monetary authority (Christiano et al., 1999) or include factors like "personalities and intellectual predilections of the policy-makers, politics, data errors and revisions, and various technical problems" as argued by Bernanke and Mihov (1998).

banks. At the four and five year horizons, the latter two intermediaries' variance decomposition is higher than that of investment funds. This might be due to the increased reliance by banks on wholesale funding markets.

Horizon	2	4	8	12	16	20
GDP	0	0	1	9	17	22
CPI	1	0	1	3	3	4
FFR	83	62	32	26	30	32
Commercial bank lending	0	0	1	6	13	18
Investment fund lending	1	6	14	11	9	12
Shadow bank lending	1	3	3	5	9	15

Table 2.2: Variance decomposition for key variables – share of variance explained by monetary policy shocks, 1984Q1 to 2006Q4 (all numbers in percent).

### 2.5.2 Ordering of variables: intermediary balance sheets before the FFR

The argument can be made that information processing and execution in companies takes time and intermediary balance sheets should therefore be ordered in the first block of variables that can only respond to monetary policy with a lag of one period. Figure 2.10 shows that commercial banks do not increase lending in the initial periods anymore, which is more in line with the credit channel of monetary transmission. Credit intermediation by investment funds is virtually unchanged from the baseline result. Shadow bank credit intermediation does not increase as much but still peaks around 0.7 percent three periods after monetary tightening.

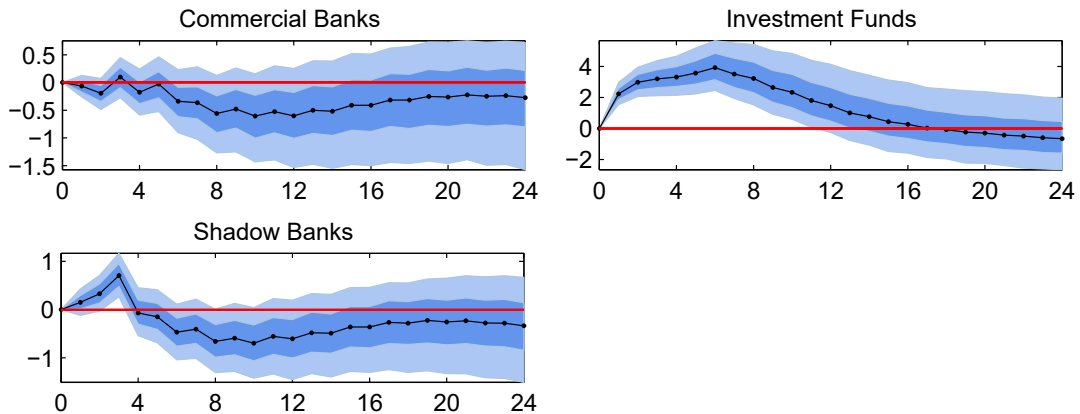


Figure 2.10: Responses of intermediaries ordered before the FFR. *Note: Baseline specification.*

### 2.5.3 Including mortgages in measures of credit

I exclude mortgages in my measures of credit, because they are the focus of a number of other studies. For completeness, Figure 2.11 shows the result when mortgages are added to the measure of credit.

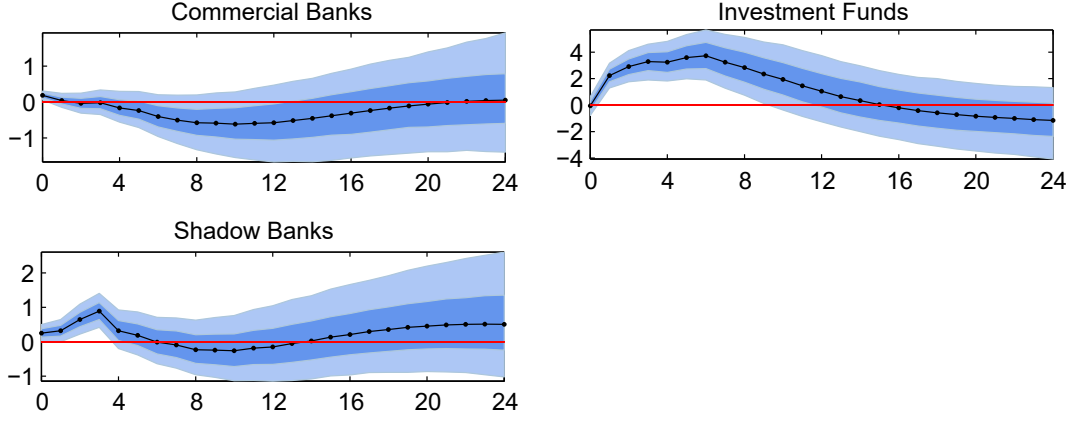


Figure 2.11: Responses of intermediaries when including mortgages in the measure of credit. *Note: Baseline specification.*

The reaction of banks is more clearly in line with the credit channel, compared to the baseline case, because credit is reduced more quickly. Investment fund credit including mortgages reacts slightly less than without mortgages. Shadow bank credit including mortgages initially reacts the same but does not fall below the baseline as much as without mortgages.

## 2.6 Conclusion

After monetary tightening shocks, banks decrease the amount of credit intermediation due to a decrease in the amount of funding they receive, which corresponds to the bank lending channel of monetary transmission. Investment funds, on the other hand, receive an inflow in funding, which allows them to increase credit intermediation. The results are robust to a change in the time horizon, the measure of credit, and the ordering of the variables in the VAR.

One key take away from the impulse responses of the different intermediaries is as follows. Since the financial crisis, credit creation has been weak, adding to the sluggishness of the recovery. At the same time, monetary policy has been near its zero lower bound, while the natural rate has been likely below zero (Tallman and Zaman, 2012). Interpreting the difference in the natural and the actual rate as a monetary policy tightening 'shock', the situation of the past years has led

banks to decrease lending, while NBFI increase lending. Since the financial crisis, many shadow banks have defaulted or been eliminated by regulation. The analysis suggests that the reduction in credit might be due to the absence of this shadow banking sector. If an increase in credit is desirable, monetary authorities facing the zero lower bound might benefit from a larger NBFI sector. Given the potentially destructive nature of some types of shadow banking institutions, investment funds would be the more agreeable solution. This interpretation has to be taken with caution, since the data in the analysis do not include the zero lower bound episode. However, this possibility should be explored in a structural analysis that is able to replicate these findings and that takes account of general equilibrium effects, which is not possible in this reduced form exercise.



## ENDOGENOUS FIRM ENTRY IN FINANCIAL ACCELERATOR MODELS

Does the financial accelerator still hold if the key variable, net worth of entrepreneurs, is endogenously chosen conditional on the business cycle? The answer is yes. I microfound the mechanism in Bernanke et al. (1999) by which new net worth in entrepreneurs is created. Households face a savings decision between state contingent and non-state contingent assets. Although the propagation of some key variables is significantly altered, the macroeconomic consequences remain broadly the same. A Bayesian estimation suggests a change in the survival rate of entrepreneurs, affecting impulse responses. The analysis suggests that models that use the financial accelerator should include endogenous firm entry if variables regarding household portfolios or shocks directly affecting firm net worth are considered.

## 3.1 Introduction

The Financial Accelerator by Bernanke et al. (1999) (henceforth BGG) has been extensively used and further developed in models that analyze financial frictions. Underlying the original analysis and much of its offspring is the assumption that borrowing constrained agents (entrepreneurs in BGG, financial intermediaries in other models) have a finite lifetime. This assumption is essential, since these agents would otherwise eventually accumulate enough wealth to escape their borrowing constraints. To facilitate aggregation, agents have a constant survival probability and new agents are born to make up for the outflow. This inflow, however, is not derived from agents' optimization, which leads to a law of motion for wealth that is not conditional on the state of the economy and may therefore affect aggregate dynamics in ways incompatible with utility-maximizing agents. Furthermore, BGG explain that the law of motion for net wealth is crucial, since it directly pins down the financial accelerator.

If new firms enter the market whenever there are any profit opportunities, financial frictions between entrepreneurs and financial intermediaries may be eliminated or at least reduced. Can the financial accelerator remain a driving force of macroeconomic fluctuations? The answer this paper suggests is yes: as long as entrepreneurs require outside equity funding and as long as fund suppliers (households) have a reason to discriminate among start-ups, model dynamics of the financial accelerator still hold. However, depending on the type of shock, several key variables are significantly affected. It is therefore worthwhile to allow for endogenous firm entry when the model relies on these variables for interpretation.

In this paper, I will endogenize the inflow of new firms, consistent with expectations about the economy. If agents could freely invest into new equity, borrowing constraints would again become non-binding, necessitating a friction. Following Wasmer and Weil (2004), I model funding market frictions analogously to those on the labor market because of their comparable characteristics of moral hazard, heterogeneity and specificity: Every period, potential entrant firms search for funding. The ultimate savers in the economy, infinitely lived households, randomly meet with potential entrants and evaluate the potential for a match. Not all meetings turn into a match, since households may dislike the individual characteristics of the potential entrant. From the macroeconomic perspective these dynamics are expressed via the search and matching framework as a microeconomically based theory of the aggregate equity markets. On the funding demand side, potential entrants take the current state of the economy into account. If firm



entry is profitable, more potential entrants will search for funding. On the funding supply side, households compare returns from new ventures with the rest of their portfolio. Households now face a trade-off: they can earn a higher interest rate on equity, but only if they find a good match. Only good matches will turn into new entrepreneurs.

The paper offers three contributions to the literature. First, firm entry is endogenized by allowing potential entrepreneurs to consider the current state and expectations over the economy. Second, this gives rise to households' motivation to fund new firms and a corresponding savings decision between risky equity and safe debt. Third, the setup has a natural interpretation of the equity premium puzzle and the risk free rate puzzle, which allows estimation of the key parameter under study: the fraction of surviving firms. The model suggests a much lower value and a resulting modification of impulse response functions.

The remainder of the paper is structured as follows: Section 2 derives the endogenous firm entry extension to the original BGG model. Section 3 contains the calibration and Bayesian estimation of parameters. Section 4 discusses the results. Section 5 concludes.

## 3.2 Extension of Bernanke, Gertler and Gilchrist (1999)

In BGG, firms finance their physical capital via net worth (or 'equity', which I will use interchangeably) and borrowing. The law of motion for aggregate entrepreneurial net worth at the end of period  $t$  is

$$N_{t+1} = \gamma V_t + W_t^e, \quad (\text{BGG.4.7})$$

where  $\gamma$  is the fraction of surviving entrepreneurs, and  $W_t^e$  is the entrepreneurial wage. The entrepreneurial equity  $V_t$  is given by the difference between the return on physical capital and borrowing costs:

$$V_t = R_t^k Q_{t-1} K_t - (R_t + EFP_t)(Q_{t-1} K_t - N_t), \quad (\text{BGG.4.8})$$

with the return to capital  $R_t^k$ , the risk free rate  $R_t$ , productive capital  $K_t$ , the price of capital  $Q_t$  and the external finance premium  $EFP_t$ . Loans make up the

remainder of the funding:

$$B_t = Q_{t-1}K_t - N_t \quad (\text{BGG.3.2})$$

New firms enter the economy to counteract the outflow. BGG assume that "the birth rate of entrepreneurs to be such that the fraction of agents who are entrepreneurs is constant". This assumptions neglects the entrepreneurial sector's ability to react to the current state and expectations about the economy. Instead of holding the fraction of agents constant, I allow an endogenous choice of entry. Potential entrepreneurs in need of equity funding pitch their projects to households on the funding market. If a household agrees to fund a potential entrepreneur, they will form a match. I abstract from the entrepreneurs' ability to work<sup>1</sup>. The new law of motion for net worth is then

$$N_{t+1} = \gamma V_t + \text{matches}_t. \quad (3.1)$$

Individual savers with liquid assets in the form of deposits  $D_{t+1}$  and individual potential entrepreneurs searching for funds with a project pitch  $v_t$  randomly meet and evaluate the potential for a match in isolation. In the aggregate, this behavior is approximated via a matching technology. Assuming a constant returns to scale matching function

$$\text{matches}_t = m(v_t, D_{t+1}) = s v_t^{1-\eta} D_{t+1}^\eta,$$

the probability  $q_t$  that a potential entrepreneur will find suitable equity funding is the number of matches per project pitch:

$$q_t = \frac{m(v_t, D_{t+1})}{v_t} = s \left( \frac{v_t}{D_{t+1}} \right)^{-\eta}. \quad (\text{E.1})$$

The probability  $f_t$  that a household will find a suitable investment is the number of matches per existing deposits:

$$f_t = \frac{m(v_t, D_{t+1})}{D_{t+1}} = s \left( \frac{v_t}{D_{t+1}} \right)^{1-\eta} \quad (\text{E.2})$$

with matching elasticity  $\eta$  and matching efficiency  $s$ .

---

<sup>1</sup>Entrepreneurial labor is included in BGG as a 'technical matter' and subsequently ignored in the complete log-linearized system of equations, since it only enters the production function with a share of  $((1 - \alpha)(1 - \Omega) =) 0.0065..$

### 3.2.1 Allowing potential entrepreneurs to search for equity funding

Potential entrepreneurs looking to establish a new firm need to find "start up" equity funding for the acquisition of physical capital by pitching their projects.<sup>2</sup> Every potential entrepreneur searches for one unit of equity funding. In case a potential entrepreneur finds funding, they can leverage up. Their gross return on capital  $R_t^k$  is then multiplied by the leverage rate  $K/N$  and the borrowing costs are multiplied by the fraction of funding that comes from loans  $B/N$ . The value of their operations  $\mathcal{E}_t^M$  will be their leveraged gross return on capital, net of borrowing costs and equity dividends  $R_t^N$  plus the value of staying matched in the subsequent period. With a probability  $\gamma$  the matched entrepreneur will keep their funding and be able to reap profits one period hence, while the firm will cease to exist and the entrepreneur will have to look for new funding otherwise.

$$\mathcal{E}_t^M = \frac{K}{N}R_t^k - \frac{B}{N}R_t^B - R_t^N + \beta\mathbb{E}_t\Lambda_{t,t+1} \left\{ \gamma \mathcal{E}_{t+1}^M + (1 - \gamma) \mathcal{E}_{t+1}^S \right\}. \quad (3.2)$$

Potential entrepreneurs that are searching for funding have a value  $\mathcal{E}_t^S$  made up of search cost  $\kappa$  and the value of future operations weighted by the likelihood of finding a match  $q_t$ :

$$\mathcal{E}_t^S = -\kappa + \beta\mathbb{E}_t\Lambda_{t,t+1} \left\{ q_t \mathcal{E}_{t+1}^M + (1 - q_t) \mathcal{E}_{t+1}^S \right\}. \quad (3.3)$$

Being on the funding market is valuable, because of the expected future profit opportunities in case of a match. If entering the funding market is costless apart from the search cost  $\kappa$ , households will keep sending potential entrepreneurs to participate until the rent from participation is zero. The free entry condition  $\mathcal{E}_t^S = 0$  and equation (3.2) result in

$$\mathcal{E}_t^M = \frac{K}{N}R_t^k - \frac{B}{N}R_t^B - R_t^N + \gamma \frac{\kappa}{q_t} \quad (3.4)$$

while (3.3) reduces to

$$\frac{\kappa}{q_t} = \beta\mathbb{E}_t\Lambda_{t,t+1} \mathcal{E}_{t+1}^M. \quad (3.5)$$

---

<sup>2</sup>The methodology follows Pissarides (2000).

Combining (3.4) and (3.5) results in the vacancy posting condition

$$\frac{\kappa}{q_t} = \beta \mathbb{E}_t \Lambda_{t,t+1} \left\{ \frac{K}{N} R_{t+1}^k - \frac{B}{N} R_{t+1}^B - R_{t+1}^N + \gamma \frac{\kappa}{q_{t+1}} \right\}. \quad (\text{E.3})$$

Potential entrepreneurs will enter the funding market until the cost of finding a match  $\frac{\kappa}{q_t}$  is equal to the benefit of having established a firm, which is the future discounted profits as well as the expected value of not having to look for new funding in the following period.

### 3.2.2 Allowing households to invest in entrepreneurial equity

A continuum of households of measure one exists, which consume, save and supply labor.<sup>3</sup> As in BGG, households can save in deposits  $D_{t+1}$  at financial intermediaries on which they earn the riskless rate  $R_{t+1}$  because the intermediary perfectly diversifies the risk from lending to firms. In addition to safe debt, households can invest in risky equity of entrepreneurs  $N_{t+1}$ . In contrast to deposits, equity is state contingent. Households are looking for a potential entrepreneur with a project that fits into their individual investment portfolio. The idiosyncratic risks of the same project may be a good fit for the portfolio of one household but a poor fit for another. The equity funding markets open at the end of the period. Since meeting potential entrepreneurs is time consuming, only a share  $f_t$  of searching households will be able to establish a match every period. The resulting number of matches is therefore the amount of deposits times the fraction of successful matches. The law of motion for entrepreneurial equity (3.1) then becomes

$$N_{t+1} = \gamma [R_t^k Q_{t-1} K_t - (R_t + EFP_t)(Q_{t-1} K_t - N_t)] + f_t D_{t+1}. \quad (\text{E.4})$$

The household problem can then be written as

$$\max_{\{C_t, D_{t+1}, N_{t+1}, H_t\}_{t=0}^{\infty}} \mathbb{E}_t \sum_{k=0}^{\infty} \beta^k [\ln(C_{t+k} + \xi \ln(1 - H_{t+k}))]$$

subject to (E.4) and the sequence of period budget constraints

$$C_t + D_{t+1}^e + N_{t+1} + T_t = W_t H_t + \Pi_t + R_t D_t^e + R_t^N N_t.$$

---

<sup>3</sup>BGG allows households to hold money, which does not affect the analysis. Likewise, I focus on the cashless limit as in Woodford (2003).

where  $D_{t+1}^e = (1 - f_t)D_{t+1}$  are the effective deposits that have not been invested in equity and that remain in banks. In equilibrium, households' effective deposits are available loans to entrepreneurs,  $D_t^e = B_t$ .  $\beta$  is the discount factor,  $\xi$  is the relative utility weight of labor.  $\Pi_t$  are profits from retailers. With  $\varrho_t$  denoting marginal utility of consumption and  $\mu_t$  denoting marginal additional utility of entrepreneurial equity over deposits, the first order conditions<sup>4</sup> for deposits and equity are given by, respectively,

$$\varrho_t = (1 - f_t)\beta\mathbb{E}_t R_{t+1}\varrho_{t+1} + f_t(\mu_t + \varrho_t) \quad (\text{E.5})$$

$$\mu_t + \varrho_t = \beta\mathbb{E}_t \{ \varrho_{t+1}R_{t+1}^N + \gamma\mu_{t+1}R_{t+1} \}. \quad (\text{E.6})$$

Equation (E.5) reduces to the commonly known Euler condition in the case that equity investments do not exist or have no additional value<sup>5</sup>, i.e., the household will increase savings until the marginal utility of consumption today equals the discounted expected marginal utility of consumption tomorrow. However, since the household's investment in equity is constrained, i.e.  $f_t < 1$ , being invested in equity is valuable, i.e.  $\mu_t > 0$ . The household will therefore increase savings until the marginal utility of consumption today equals the *probability* of consuming tomorrow  $(1 - f_t)$  times its value (the discounted expected marginal utility of consumption tomorrow) plus the *probability* of investing in equity  $f_t$  times that value. The value of investing in equity is given by Equation (E.6), which shows that the marginal utility of investing in equity  $\mu_t + \varrho_t$  is tomorrow's discounted dividend weighted by marginal utility of consumption, as well as the future value of staying matched.

### 3.2.3 Dividend Bargaining

Because of the existence of search frictions, entrepreneurs enjoy a rent on established matches. I assume that the dividend entrepreneurs pay on funds raised is determined via Nash bargaining over these surpluses.  $\omega$  is the relative bargaining power of households. Dividends  $R_{t+1}^N$  are negotiated to maximize a convex combination of the surpluses,

$$R_{t+1}^N = \operatorname{argmax} \quad \omega \ln \mathcal{H}_t + (1 - \omega) \ln \mathcal{E}_t.$$

The marginal surplus potential entrepreneurs stand to gain from starting a

<sup>4</sup>First-order conditions w.r.t. labor are standard.

<sup>5</sup>Iff  $\mu_t = 0$ , Equation (E.5) holds for all  $f_t$ .

firm is the difference between the value of an matched entrepreneur  $\mathcal{E}^M$  versus an unmatched entrepreneur  $\mathcal{E}^S$  as defined in Equations (3.2) and (3.3). Assuming free entry, the value of an Entrepreneur is

$$\mathcal{E}_t = \mathcal{E}_t^M - \mathcal{E}_t^S = \frac{K}{N}R_t^k - \frac{B}{N}R_t^B - R_t^N + \gamma \frac{\kappa}{q_t}. \quad (3.6)$$

For a household the value of being matched with a potential entrepreneur  $\mathcal{H}_t^M$  is made up of the dividend  $R_t^N$  that they receive plus the future discounted expected value of staying matched with the probability  $\gamma$  versus having to look for new opportunities in case the firm dies with probability  $(1 - \gamma)$ :

$$\mathcal{H}_t^M = R_t^N + \beta \mathbb{E}_t \Lambda_{t,t+1} \{ \gamma \mathcal{H}_{t+1}^M + (1 - \gamma) \mathcal{H}_{t+1}^S \}. \quad (3.7)$$

The value of searching for good opportunities and saving the funds at the financial intermediary at the risk less rate  $R_t$  in the meantime is

$$\mathcal{H}_t^S = R_t + \beta \mathbb{E}_t \Lambda_{t,t+1} [f_t \mathcal{H}_{t+1}^M + (1 - f_t) \mathcal{H}_{t+1}^S], \quad (3.8)$$

where they will find a suitable match in the next period with the probability  $f_t$  from Equation (E.1). The surplus from funding an entrepreneur is the difference households receive in interest rates together with the value they have from staying matched,

$$\mathcal{H}_t = \mathcal{H}_t^M - \mathcal{H}_t^S = R_t^N - R_t + \beta \mathbb{E}_t \Lambda_{t,t+1} (\gamma - f_t) \mathcal{H}_{t+1}. \quad (3.9)$$

The first-order condition for dividend bargaining can now be solved and is

$$\frac{\omega}{\mathcal{H}_t} = \frac{(1 - \omega)}{\mathcal{E}_t}. \quad (3.10)$$

In order to solve for the dividend I need to eliminate  $\mathcal{H}_{t+1}$  in Equation (3.9). I can rewrite Equation (3.9) into

$$\mathcal{H}_t = R_t^N - R_t + (\gamma - f_t) \frac{\omega}{1 - \omega} \frac{\kappa}{q_t} \quad (3.11)$$

by solving Equation (3.10) one period forward and substituting for  $\mathcal{E}_{t+1}$  from Equation (3.5).

Substitution Equations (3.6) and (3.11) into Equation (3.10) results in the

dividend that entrepreneurs pay for funds raised:

$$R_t^N = R_t + \omega \left[ \frac{K}{N} (R_t^k - R_t) + \kappa \frac{f_t}{q_t} \right]. \quad (\text{E.7})$$

If household bargaining power is zero, entrepreneurs can get away with paying only the interest rate  $R_{t+1}$  that banks pay on their deposits. With increasing bargaining power, entrepreneurs need to share expected profits, i.e., the leveraged net return on capital, and the value of staying matched with investing households, i.e., the saved cost of having to look for funding in the following period.

### 3.2.4 Resources and Policy

The aggregate resource constraint from BGG is modified to reflect the cost of posting vacancies

$$Y_t = C_t + I_t + G_t + C_t^e + \kappa v_t. \quad (\text{E.8})$$

The monetary policy rule and shock processes are unchanged from BGG.

## 3.3 Parameterization

In this section, I will first describe some general characteristics of the model that suggest statements about the equity premium and the risk-free rate puzzles. I will then calibrate the model parameters, most of which are taken directly from BGG. The model is solved via first order perturbation around the deterministic steady state.

### 3.3.1 Implications for the risk free rate

The conventional household Euler condition requires the risk-free rate  $R_{t+1}$  in equilibrium to be equal to the reciprocal of the time-varying intertemporal marginal rate of substitution<sup>6</sup>. In the deterministic steady state, the risk-free rate is therefore the reciprocal of the household discount rate. Contrast this with the Household Euler Equation (E.5). If holding equity is more valuable than holding deposits ( $\mu_t > 0$ ), the risk-free rate is less than  $\beta^{-1}$ . Every unit of deposits has the potential to be matched with an entrepreneur looking for funding. Households will

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<sup>6</sup>Specifically,

$$\mathbb{E}_t\{R_{t+1}\} = \frac{1}{\mathbb{E}_t\{\varrho_{t+1}\}} \left[ \frac{\varrho_t}{\beta} - \text{cov}(R_{t+1}, \varrho_{t+1}) \right].$$

therefore hold liquid assets in the form of deposits not just to reap the risk-free rate, but also to acquire firm equity. In equilibrium, this over-saving will result in a risk-free rate that is lower than  $\beta^{-1}$ .

Since each household does not necessarily find the desired equity investments each period ( $f_t < 1$ ) and since firms eventually die ( $\gamma < 1$ ) necessitating the renewed search for appropriate equity investments, the equity return  $R_{t+1}^N$  has a premium over the risk-free rate.

The model therefore attributes the existence of the equity premium to households' imperfect search for appropriate portfolio holdings. That the risk-free rate is lower than common discount rates would suggest liquid assets (of which risk-free assets like deposits are the most common type) are not only held for savings purposes but also for readily investing in desired equity. Since the model has interpretations of these two important puzzles in the macro-finance literature, I will use data common to the equity premium puzzle first discussed by Mehra and Prescott (1985).

#### 3.3.2 Calibration

Most of the parameters have annualized values from the quarterly BGG model, which I will not discuss. The rest of the parameters using other sources are calibrated as follows.

For the steady state equity return  $R^N$ , I use the real return on the S&P 500 stock index. Original data from 1889 to 1990 by Shiller (1992) are updated until 2004. Calculation follows the improved methodology by Kocherlakota (1996). The steady state real return on risk-less savings are identified with the real return on relatively risk-less securities as in Mehra and Prescott (1985). In order to achieve a risk-less return that is lower than  $\beta^{-1}$ , the steady state probability for a household of finding suitable investments is about 20%. For symmetrical purposes, the corresponding probability for potential entrepreneurs is set to the same value.

The annual risk spread on bank lending,  $R^k - R$ , is equal to 240 basis points using the same methodology as BGG for the average yearly spread between the prime lending rate and 6-month Treasury bill secondary market rate. The ratio of capital over equity,  $K/N$ , is 3. Since firm debt makes up the remaining financing,  $B/N$  is equal to 2. For a detailed description of the data, see Appendix B.4.

Several new parameters are introduced. For an equity price premium of 6% as given in the data, the household bargaining power with respect to dividends,  $\omega$ ,



has to be 0.63; the search cost  $\kappa$  has to be 0.019. The magnitude of the search cost can be understood when looking at the value of establishing a match, Equation (3.9), which consists of differences in interest rates. The search cost is higher than the net risk-free rate, but lower than net borrowing or equity costs. If the search cost were lower than the net risk-free rate, more potential entrepreneurs would borrow from their respective households to participate in the funding market. If the cost were higher than their borrowing and equity costs, it would never make sense to establish a match. The matching elasticity  $\eta$  is not directly pinned down by the data. I assume an efficient underinvestment in equity, i.e., the Hosios condition, which implies that the elasticity of the matching function with respect to deposits,  $\eta$ , equals the households' share of the matching surplus,  $\omega$ .

Symbol	Value	Description	Source
Households			
$\beta$	0.96	Discount rate	BGG
$\phi$	3	Labor supply elasticity	BGG
$f$	0.2	StSt probability of finding equity	MP
$q$	0.2	StSt probability of finding funding	MP
$\omega$	0.63	Household bargaining power	data
Interest Rates			
$R$	0.014	Real annual return on risk-less bond	MP
$R^N$	0.077	Real annual return on equity	MP
$R^k - R$	0.024	Risk spread	data
Economy			
$\alpha$	0.35	Capital share	BGG
$(1 - \alpha)(1 - \Omega)$	0.64	Household labor share	BGG
$\delta$	0.1	Depreciation rate	BGG
$\psi$	0.25	Elasticity of price adjustment	BGG
$\gamma$	0.11	Death rate	BGG
$\theta$	0.5	Calvo price setting	BGG
$K/N$	3	ratio of capital over equity	data
$B/N$	2	ratio of debt over equity	data
$\eta$	0.63	Matching elasticity	data
$\kappa$	0.019	Search cost	data
Government			
$G/Y$	0.2	Steady state proportion of government expenditures	BGG
$\kappa_\pi$	0.11	Inflation coefficient of Taylor rule	BGG
$\rho_i$	0.66	Smoothing parameter of the Taylor rule	BGG
Shock Processes			
$\rho_g$	0.81	Persistence Govt	BGG
$\rho_a$	0.81	Persistence TFP	as $\rho_g$

Table 3.1: Calibrated parameter values. *Note: In the Source column, BGG refers to parameter values from Bernanke et al. (1999) and MP refers to Mehra and Prescott (1985).*

### 3.3.3 Estimation of the survival rate of entrepreneurs

BGG pin down the survival rate of entrepreneurs  $\gamma$  to 0.9728 quarterly to imply some steady state outcomes. In fact, these outcomes are independent of  $\gamma$ . Given the centrality of the parameter in this extension of the model, I will estimate  $\gamma$  using Bayesian methods. I use data from the Mehra and Prescott (1985) study on consumption, the risk-free rate and the equity return to arrive at a value of  $\gamma = 0.55$  (yearly), which translates into a  $\gamma = .89$  on a quarterly basis, i.e., much lower than in BGG.

Such a rate of firm 'deaths' is implausibly high. In order to align the rate with empirical realities I need to reinterpret the parameter. Given the model and the data, this parameter can alternatively be understood as firm equity being acquired by or merged with other firms.

## 3.4 Results

The basic mechanism of expansionary monetary policy shocks is the same as in BGG and can be seen in the light blue, dash-dot line<sup>7</sup> in Figure 3.1: after an unanticipated decrease in the monetary policy rate, the demand for capital increases. This stimulates investment and the price of capital. The unexpected increase of return on capital raises entrepreneurial net worth, decreasing the external finance premium. This results in the well-known multiplier effect of the financial accelerator.

The endogenous firm entry model has very comparable results for several important variables, including output, inflation, hours worked. However, it differs from BGG in some key real and financial variables, including investment, net worth and the EFP. The mechanism is as follows. Note that firms gain from a fall in the EFP, because it becomes cheaper to find external finance. At the same time, a low EFP means that starting new firms is not as profitable, since the return on capital is only slightly higher than the risk-free rate, i.e., the EFP does not fall as much as in BGG. An unexpected monetary policy rate decrease will therefore result in fewer potential entrepreneurs looking for start-up funding. This results in an increase in the equity finding rate. Likewise, households looking for appropriate equity investments will have a harder time finding them. Aggregate net worth does not increase as much and the EFP will stay higher. Capital investments will

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<sup>7</sup>The difference in the IRFs to the BGG handbook chapter come from the difference in the leverage, which BGG pin down at 2 while in the data I find 3 to be a more applicable leverage.

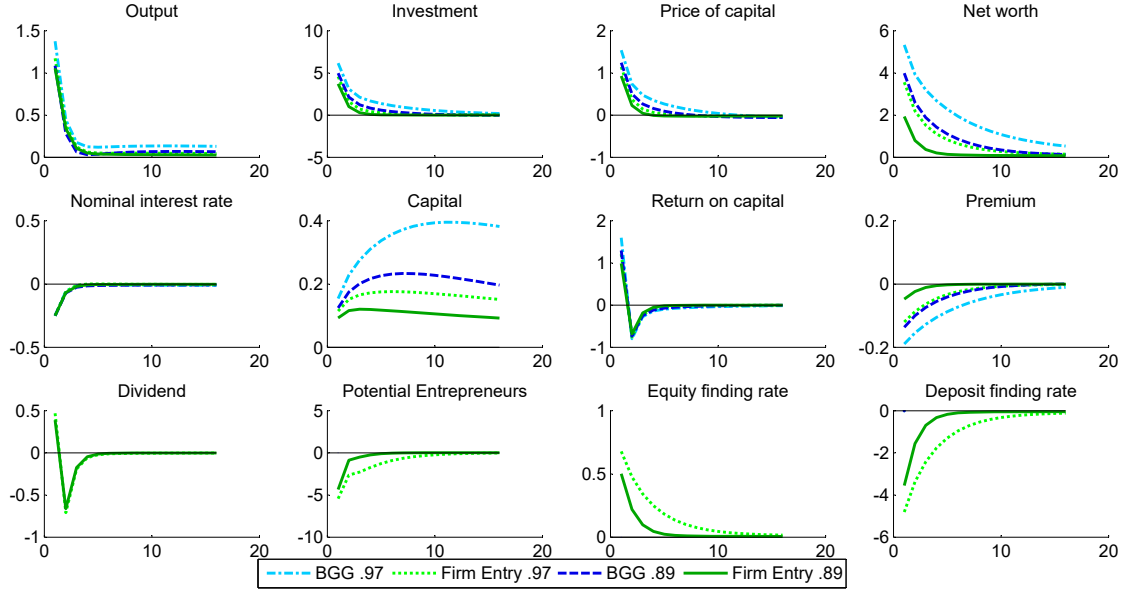


Figure 3.1: Monetary Policy Shock

*Note: Impulse Response Functions to an unanticipated 25 basis point decrease in the nominal interest rate. The horizontal axis reports quarters since the shock. The vertical axis reports deviations from steady state.*

therefore not rise as much.

Adjusting the survival rate down as suggested by the Bayesian estimation decreases the magnitude of the response to shocks. In the original BGG model, the muted reaction is due to a larger share of new firms, which are not affected by the shock. The inflow of new funding is not based on optimizing behavior by any agents and happens regardless of the shock. This is different in the endogenous firm entry model with an adjusted survival rate. Since the shock decreases the profitability of firms, fewer potential entrepreneurs will establish them.

TFP shocks for the case of endogenous firm entry are not substantially different from the BGG case. After a positive TFP shock, production becomes more efficient and the resulting price decrease stimulates demand. Capital investments become more efficient and more investments into capital will be undertaken, increasing the price of capital. All these result in a higher return to capital and a decrease in the EFP, further stimulating investments. This is the case independently of the survival rate

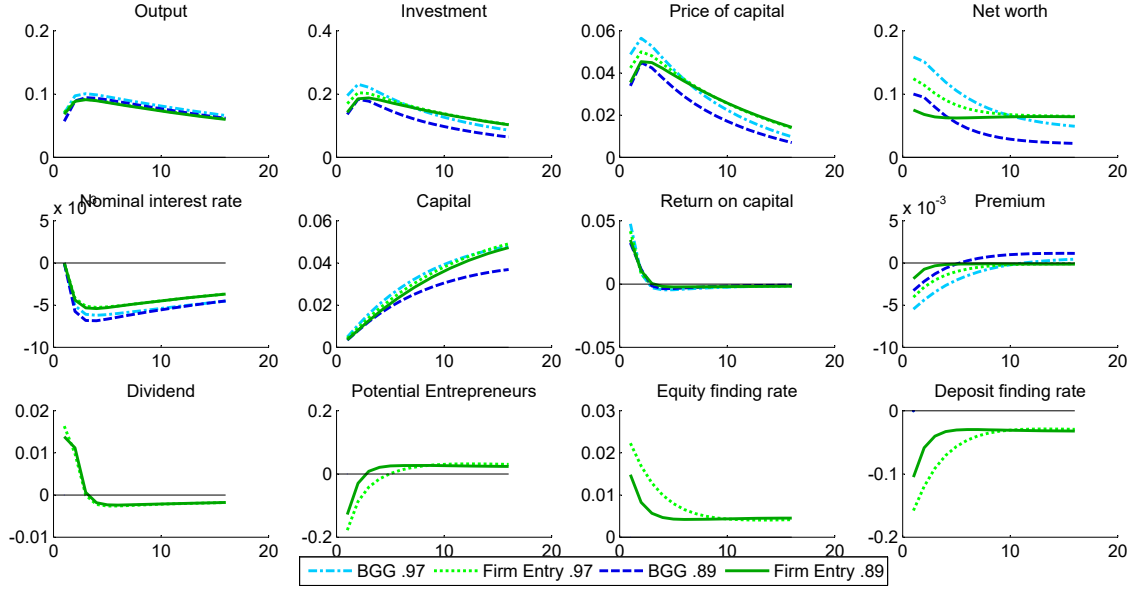


Figure 3.2: TFP Shock

*Note: Impulse Response Functions to an unanticipated one standard deviation increase in TFP. The horizontal axis reports quarters since the shock. The vertical axis reports deviations from steady state.*

### 3.4.1 The External Finance Premium

The External Finance Premium (EFP) is the driving force of the Financial Accelerator. If the size of borrowers' balance sheets move procyclically, BGG suggests that the EFP should be counter-cyclical. The data are not clear on this issue. De Graeve (2008) estimates a timeline for the EFP from a DSGE model using post-WW2 US data that is generally increasing in times of growth and decreasing after recessions. Martinez-Garcia (2013) finds a small but positive correlation between output and the EFP, proxied by the spread between Baa-rated corporate bond yields and the 20y Treasury bill rate. Gelain (2010) shows that the EFP for an estimated model of the Euro area may have either cyclicity depending on the type of shock.

As can be seen in the IRFs to TFP shocks, Figure 3.2, the EFP may react cyclically to shocks if the survival rate  $\gamma$  becomes smaller. The reason is that a smaller survival rate decreases aggregate net wealth more strongly, increasing the leverage ratio and therefore the probability of default. However, shocks that affect demand for goods positively will still increase investments, since new firms entering the economy expect profits *despite* the heightened EFP. A low EFP may then be the result of inefficient firms having left the market.

## 3.5 Conclusion

This paper has shown that firm entry in financial accelerator models can be made endogenous and that the mechanism of the original BGG model still holds. Several macroeconomic variables differ in the case of firm entry. First of all, aggregate net worth is generally not affected as severely by shocks, since profit opportunities will usually be scooped up by new entrants. This happens because potential entrants will vary their efforts at establishing a firm with the business cycle.

In addition, the resulting model offers an interpretation of the equity premium puzzle: Equity dividends offer a high yield, because not every equity issuer is a good match for every household portfolio. Since searching for the right assets takes time, and because there is a lack of demand for equities, matched equity buyers and sellers enjoy a rent on their activities. In addition, the risk free rate is below the discount rate in steady state because risk free assets offer a transactional premium, as they can be used to buy other, higher yielding assets.

Following this interpretation, an estimation of the model with data commonly used in the equity premium literature suggests a lower value for the fraction of surviving entrepreneurs than the original BGG paper claims. This change in the value affects the propagation of some shocks significantly. It may therefore be advisable to use endogenous firm entry in other models, if parameters are estimated or if household savings decisions are analyzed.

In the original BGG, firms exit the economy with a fixed probability every period. It is a natural extension to incorporate endogenous firm exit into this analysis.



## IMPLICATIONS OF SHADOW BANK REGULATION FOR MONETARY POLICY AT THE ZERO LOWER BOUND

Empirical evidence shows that monetary policy tightening affects three types of financial institutions in different ways: banks decrease lending, while shadow banks and investment funds increase lending. I develop an estimated monetary DSGE model with funding market frictions that is able to replicate these empirical facts. In a counterfactual exercise I study how the regulation of shadow banks affects an economy at the zero lower bound (ZLB). Consumption volatility is reduced when shadow bank assets are directly held by commercial banks. Alternatively, regulating shadow banks like investment funds results in a milder recession during, and a quicker escape from, the ZLB. The reason is that a recessionary demand shock that moves the economy to the ZLB has similar effects to a monetary tightening due to the inability to reduce the policy rate below zero.

## 4.1 Introduction

The financial sector has come under increasing scrutiny following the recent financial crisis. With the regulatory community planning to especially constrain the role of shadow banks<sup>1</sup> in aggregate credit supply (Financial Stability Board, 2016; Claessens et al., 2012), the resulting excess credit demand will be met by commercial banks and other non-bank financial institutions (NBFI). The relative size of commercial banks in the financial sector matters for monetary policy transmission, because bank lending is considered special (Brunnermeier et al., 2013; Peek and Rosengren, 2013; Boivin et al., 2010). At the same time, monetary policy makers have been faced with a reduced ability to lower policy rates due to the zero lower bound (ZLB). This paper studies how different financial sector configurations affect the behavior of an economy at the ZLB.

I take a standard monetary DSGE model and develop a financial sector with commercial banks, shadow banks and investment funds<sup>2</sup> that is able to replicate empirical impulse response functions and key aggregate business cycle statistics outside the ZLB. I implement a ZLB and conduct counterfactual analyses in which shadow banks are eliminated from the model to mimic financial regulation. Since the fundamentals of the real economy are not affected by the configuration of the financial system, credit demand from the real sector stays constant and will either be filled by commercial bank credit or investment fund credit. I argue that a recession at the ZLB is milder and shorter lasting if the credit system relies more on investment funds rather than on commercial banks.

The reason is as follows. Monetary tightening leads households to shift savings out of bank deposits and into higher yielding liabilities of investment funds, which therefore increase lending. For commercial banks the reduction in resources leads to a decrease in lending, which is called the bank lending channel. Because the lower bound on monetary policy prevents the policy rate from falling to the level that would be chosen with unconstrained monetary policy, the propagation

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<sup>1</sup>Shadow banks have seen a reduction in credit intermediation by 50% since the financial crisis (see Figure C.3 in Appendix C.3). I define shadow banks as ABS Issuers, Finance Companies, Funding Corporations and Security Brokers and Dealers. Their fixed income private credit intermediation, which is defined as loans, bonds, consumer credit and commercial paper, totaled about 35% of all credit to the economy before the 2008 financial crisis. This group's common characteristic is that they occupy a central place in the internal functioning of financial markets between other financial institutions. Households typically do not fund shadow banks directly.

<sup>2</sup>Investment funds are mutual funds and money market funds. Before the financial crisis these institutions channeled about 25% of private credit to the real sector, and they have grown since then. Unlike shadow banks, investment funds are directly accessible to households and therefore feature in household savings decisions.



mechanism of a ZLB-inducing demand shock resembles a monetary policy tightening: Households prefer higher yielding assets to deposits, which activates the bank lending channel. This mechanism is weakened and credit reduction is dampened during a downturn, if the financial sector is more reliant on non-deposit funding provided by investment funds.

I contribute to the existing literature in three ways: i) by explaining and replicating the empirical reactions of non-bank financial institutions (NBFI) to monetary policy in a monetary DSGE model; ii) by likening the mechanism of a ZLB-inducing demand shock to a response to monetary tightening; and iii) by analyzing different financial sector configurations regarding their effectiveness to escape the ZLB on nominal interest rates.

Including a distinct investment fund sector in the analysis requires some explanation. I add them next to commercial banks and shadow banks for three reasons. First, investment funds rely on equity funding, which is state contingent, while commercial banks rely largely on deposit funding, which is non-state contingent. Investment funds therefore represent the opposite to banks in terms of funding and warrant a different type of model friction. Second, although investment fund regulations are currently being tightened, regulatory authorities treat them as a necessary part of the financial system, while the existence of shadow banks is more challenged. Finally, the relevance of the structure of the financial system is an important question in the literature (see e.g., Allen and Gale, 2001), which I can explore in the context of my model. This discussion is crucial for regions currently assessing different financial market structures. For example, in the European Union the Capital Markets Union proposal suggests a move away from a bank-dependent financial system to a more capital markets based system.

In Section 2, I conduct an empirical analysis of NBFI responses to monetary policy shocks, which motivates the analysis. Next, I explore how a model with three types of intermediaries and the incorporation of a savings decision by households can replicate and account for these empirical observations. Section 4 contains the model analysis, including calibration and Bayesian estimation, impulse response functions to monetary policy shocks and business cycle effects of eliminating shadow banking. Section 5 contains the ZLB analysis and reaction of the economy under different financial sector configurations, as well as the comparison of a demand shock at the ZLB to a monetary tightening. Section 6 concludes.

## **Related Literature**

This paper mainly connects to four different strands of the literature. First, there are a number of papers focusing on different aspects of shadow banking.<sup>3</sup> I do not look at crisis periods and the accompanying effects of fire sales, bankruptcy and regime transition. Instead, I focus on business cycle consequences of different financial system configurations after they have been implemented.

The second strand of the literature analyses the credit channel of monetary policy. The credit channel posits that following monetary tightening the amount of credit in an economy is reduced, which amplifies traditional interest rate and asset price channels.<sup>4</sup> This channel is split up in the balance sheet channel and the bank lending channel.<sup>5</sup> The latter has often been challenged in light of banks' abilities to substitute to non-deposit funding.<sup>6</sup> However, there is a large empirical literature that finds evidence for the bank lending channel.<sup>7</sup> This paper introduces a mechanism that allows the financial sector to substitute into other sources of funding and therefore decrease the effectiveness of the bank lending channel. A related literature analyzes monetary policy effectiveness. Over the past several decades unexpected monetary policy shocks appear to have had less and less of an influence on the real economy.<sup>8</sup> This is sometimes explained by developments in capital and financial markets.<sup>9</sup> This paper adds to the understanding of how the financial market structure, especially its funding via savers, influences the effectiveness of monetary policy.

Third, the paper adds to the understanding of economies that are constrained

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<sup>3</sup>Meeks et al. (2014) analyze financial stability and consider shadow banks as off-balance sheet vehicles of commercial banks to unload risky loans. Verona et al. (2013) study adverse effects of excessively easy monetary policy and understand shadow banks as financial intermediaries specializing in less risky loans akin to bond issuance by investment banks. Moreira and Savov (2014) analyze the way in which shadow bank liability liquidity characteristics change over the business cycle. Goodhart et al. (2012) study different regulatory regimes to stop fire sales by shadow banks and take the opposite view to Verona et al., considering shadow banks to be less risk averse, but still funded by the commercial banking sector, comparable to off-balance sheet vehicles as in Meeks et al. Gertler et al. (2016) focus on the role of wholesale banking in transmitting crises to the real sector.

<sup>4</sup>For a simple exposition in the IS/LM framework, see Bernanke and Blinder (1988).

<sup>5</sup>See Bernanke and Gertler (1995). The balance sheet channel is underlying the financial accelerator as developed in Bernanke et al. (1999)

<sup>6</sup>Romer and Romer (1990) argue that bank loan supply is insulated from monetary policy if banks can frictionlessly find non-depository funding.

<sup>7</sup>Early support from aggregate data comes from Kashyap et al. (1993). Identification issues, however, necessitate more detailed data, which were advanced by Kashyap and Stein (1995).

<sup>8</sup>For an empirical exploration, see e.g., Primiceri (2005) and Boivin and Giannoni (2006). For a structural explanation, see Justiniano and Primiceri (2008).

<sup>9</sup>See Jermann and Quadrini (2006) and Dynan et al. (2006) as well as a critique by den Haan and Sterk (2011).

by a ZLB. Although the theoretical idea has existed for some time<sup>10</sup>, empirical studies were limited to the Japanese experience. Since the financial crisis of 2008, several studies have focused on how an economy can escape the ZLB via fiscal policy or unconventional monetary policy.<sup>11</sup> This paper instead focuses on how the overall composition of the financial sector facilitates resilience to the negative consequences of a ZLB.

Lastly, the theoretical mechanism developed in this paper is related to the search and matching literature. The initial development focused on explaining the dynamics of the labor market and replicating key statistics.<sup>12</sup> It has since found applications to other markets, including money and credit relationships.<sup>13</sup> Following Wasmer and Weil (2004), I model funding market frictions analogously to those on the labor market because of their comparable characteristics of "moral hazard, heterogeneity and specificity". However, in my model the amount of deposits changes endogenously.

## 4.2 Evidence on the reaction of financial institutions to monetary policy shocks

This section summarizes the empirical reaction of lending by commercial banks, shadow banks and investment funds to monetary tightening. I follow Christiano et al. (1999) in the selection of variables and the identification of shocks by assuming that the monetary policy makers choose their target for the federal funds rate based on their information set  $\Omega_t$ . Variables contained in  $\Omega_t$  are contemporaneous measures for GDP, the CPI and the index of sensitive commodity prices (comprising the first block of variables). The remaining variables are M2 money stock, total central bank reserves, non-borrowed reserves and the amount of lending for each intermediary (comprising the second block). Policymakers observe the second set of variables only with a lag of one period. Since I am only interested in the effects of monetary policy shocks, the ordering of variables within their blocks does not matter. I use the Federal Funds Rate (FFR) as a proxy for monetary policy.

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<sup>10</sup>See Eggertsson and Woodford (2003) for a theoretical treatment.

<sup>11</sup>Christiano et al. (2011) explain why the government spending multiplier at the ZLB can generally be larger than 1, while Albertini and Poirier (2015) and Christiano et al. (2016) show potentially expansionary effects of unemployment benefits. Gambacorta et al. (2014) explore the effectiveness of unconventional monetary policy.

<sup>12</sup>The seminal paper is Mortensen and Pissarides (1994).

<sup>13</sup>See den Haan et al. (2003) and Wasmer and Weil (2004) for early contributions and Gu et al. (2016) and Beaubrun-Diant and Tripier (2015) for current applications.

I use quarterly data from 1984:1 to 2006:4. I exclude data after 2006, because of the start of the global financial crisis, which changed the regulation and risk perception of the financial sector, as well as the binding zero lower bound on monetary policy (in 2008), which complicates the identification of monetary policy shocks. The analysis starts in 1984, because of a likely structural break in the conduct of monetary policy between the pre- and post-Volcker chairmanship of the Federal Reserve, see Clarida et al. (2000).

For the purpose of this paper I define shadow banks as intermediaries that are generally debt funded by other institutional investors and banks. They are ABS Issuers, Security Brokers and Dealers, Finance Companies and Funding Corporations. Investment funds are open ended funds that issue and redeem equity fund shares directly. Households can generally invest in them. Open ended funds are Mutual Funds and Money Market Funds. Banks take deposits from households and originate loans directly. They are U.S. Depository Institutions and Credit Unions. Data for the financial sector variables are from the Financial Accounts of the United States (see Table C.1 for details). I include loans, bonds, consumer credit and commercial paper as a measure of credit. Intermediaries typically fund substantial amounts of securities issued by the government and municipalities, as well as debt backed by government-sponsored entities (GSEs). I purposely exclude these items in the measure of real economy credit since securities with implicit or explicit governmental guarantees are often assumed for liquidity reasons or used as collateral and may therefore serve a different purpose than to profit from lending.

I use four lags to capture the dynamic properties of the quarterly dataset. Because of the large number of parameters, I adopt an estimation approach with Bayesian shrinkage of VAR parameters as in Banbura et al. (2010). The model is estimated in log-levels (except for the FFR, which is in levels). All nominal variables are transformed into real variables.<sup>14</sup>

Figure 4.1 shows the results of the structural analysis. Following a 100bp increase in the FFR, lending by commercial banks initially stays constant, before it drops by about 4% after three to four years. The lag in the reaction contrasts with the literature that uses exact timing of FOMC announcements.<sup>15</sup> This is potentially due to the specific type of asset classes I focus on. Although banks reduce lending for the general pool of loan applicants, informal lending relationships and formal credit commitments require banks to support some clients with additional

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<sup>14</sup>I explain the approach in more detail in Chapter 2, where I also conduct robustness exercises regarding time horizon, as well as selection and ordering of variables.

<sup>15</sup>See, e.g., Francis et al. (2011).

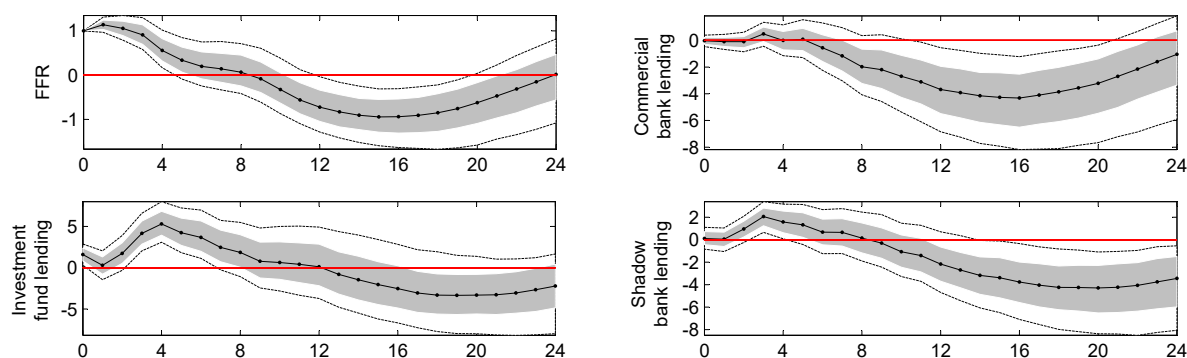


Figure 4.1: Responses of intermediaries to a contractionary monetary policy shock. *Note:* Empirical impulse responses of the federal funds rate and credit by commercial banks, investment funds and shadow banks to an unanticipated 100 basis point increase in the federal funds rate. The horizontal axis reports quarters since the shock. The vertical axis reports percentage deviations from the unshocked path. Shaded regions are 32nd-68th and 10th-90th percentiles of 1000 draws. The full set of variable responses are in Figure C.4 in Appendix C.3. See Chapter 2 for additional information and sources.

funding (Morgan, 1998). On net, this might lead to little change in credit at first before bank balance sheets give way to funding pressures. Investment fund lending increases by more than 5% during the first year, before it falls back to the baseline after two to three years. Lending by shadow banks increases by about 2% during the first year. It slowly drops below baseline and bottoms out after five years.

The behavior of banks is in line with the credit channel of monetary policy: because of an increase in funding costs for borrowers and their customers, profits are reduced and collateral values drop. The increased riskiness of borrowers translates into higher interest rates demanded by banks, which reduces credit demand in line with the balance sheet channel (Bernanke et al., 1999). At the same time, bank creditors substitute to higher yielding assets (Drechsler et al., 2016), which reduces the amount of resources available to banks, which corresponds to the bank lending channel. The behavior of shadow banks is often explained via regulatory arbitrage: because commercial banks face binding leverage and capital restrictions, they channel resources via less strictly regulated shadow banks that they own and control. Money market funds pass on higher returns to investors more quickly than banks do on their deposits and therefore receive an inflow in funding, which is passed on as additional lending (see Chapter 2).

There are several studies that find complementary evidence. Nelson et al. (2015) conduct a similar analysis, but differ in regards to the definition of shadow

banks and asset classes.<sup>16</sup> Their estimation in log differences finds commercial bank asset growth dropping after monetary tightening, while shadow bank asset growth increases. In a Factor-Augmented VAR, Igan et al. (2013) study the effects of monetary policy on intermediary balance sheets from 1990:1 to 2008:2. They similarly find that money market funds (a type of investment fund) increase assets after monetary tightening. Security brokers and dealers (a type of shadow bank) also increase assets. Pescatori and Sole (2016) estimate a VAR with banks, ABS issuers and finance companies, but also include government sponsored entities (GSEs), agency and GSE-backed mortgage pools and life insurance companies. The authors conclude that monetary tightening decreases aggregate credit intermediation, but increases the relative sizes of non-banks, thereby potentially increasing systemic risk by pushing credit intermediation to less regulated sectors. den Haan and Sterk (2011) estimate the response of mortgage and consumer credit held by banks and non-banks. Bank mortgages and consumer credit decline or stay relatively flat, respectively, after monetary policy tightening, while non-bank holdings increase.

Next, I explore how a monetary DSGE model with financial frictions can replicate and explain the empirical results.

### 4.3 A monetary DSGE model with three types of financial institutions

Although the financial sector has been incorporated into DSGE models recently, it is still largely treated as a relatively homogeneous entity. I follow the call by Woodford (2010) for "a framework for macroeconomic analysis in which intermediation plays a crucial role and [...] which also takes account of the fact that the U.S. financial sector is now largely market-based." I employ a monetary DSGE model with sluggish price setting to generate nominal frictions, which allows shocks to the nominal monetary policy rate to affect real variables.

The structure of the shadow banking sector and its relationship to the rest of the financial sector is comparable to Meeks et al. (2014) and Gertler et al. (2016). Debt and equity financing are modeled using two different types of frictions. Debt

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<sup>16</sup>They look at the change in the total size of the balance sheets instead of a single asset class (fixed income holdings with the real sector as in this paper). This is an imperfect measure when one is interested in the effectiveness of the credit channel, as financial intermediaries are invested in equity as well as governmental and municipal debt, which are often held for collateral purposes.

financing via the moral hazard problem as in Gertler and Kiyotaki (2010) and Gertler and Karadi (2011) guarantees that as long as the intermediary does not exceed a maximum amount of leverage per intermediary value, creditors are indifferent towards the absolute amount of debt that they hold. This introduces endogenously varying leverage in to the model. Without explicitly modeling it, this can be understood as deposit insurance for commercial banks and pledged, or asset backed, debt for shadow banks.

Equity financing is risky. Since equity investors participate in the state-contingent returns of the intermediary, households are only willing to hold equity claims that have an underlying returns profile that fits into the individual household's portfolio. An equity return that is higher than the interest rate on debt captures this riskiness. Although not modeled explicitly, this heterogeneity on the micro level is captured via a search and matching mechanism: only a fraction of households agree to the terms of the potential intermediaries that they meet on the equity funding market. This friction introduces an endogenously varying value for fund shares, while keeping households from investing all of their savings in higher yielding assets. Households therefore change the amount of available savings for investment purposes depending on the state of the business cycle. In addition, this friction allows me to solve the savings decision of households via a linear approximation.

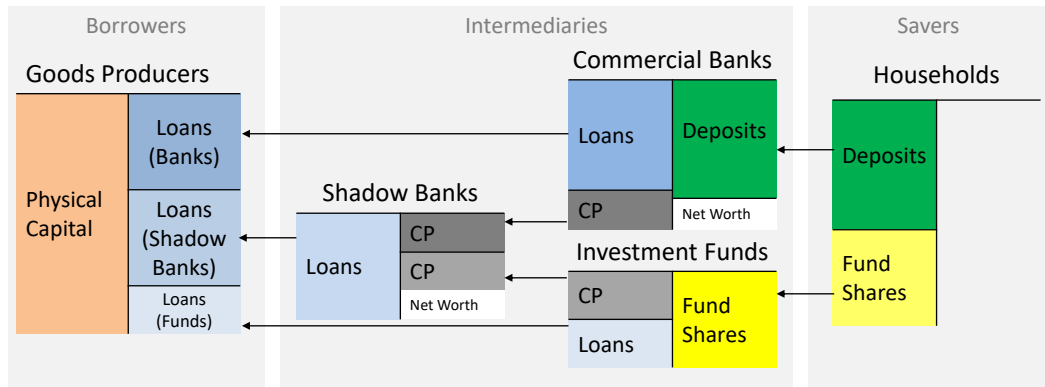


Figure 4.2: Balance sheets of key agents in the economy. *Note: In addition, the economy is populated by capital producers and monopolistically competitive retailers. A central bank is the source of monetary disturbances. CP = Commercial Paper.*

In addition to the five agents shown in Figure 4.2, the economy is populated by capital producers and monopolistically competitive retailers. A central bank conducting monetary policy is the source of monetary disturbances and completes the model.

### 4.3.1 Households

A continuum of households of measure one exists that consume, save in a portfolio of assets and supply labor. They maximize discounted lifetime utility

$$\max_{\{C_t, L_t, D_t, N_t^{IF}\}_{t=0}^{\infty}} \mathbb{E}_0 \sum_{t=0}^{\infty} \left( \prod_{i=0}^t \beta_i \right) \left[ \ln(C_t - hC_{t-1}) - \frac{\chi}{1+\varphi} L_t^{1+\varphi} \right]$$

subject to the sequence of period budget constraints

$$C_t + D_t^e + N_t^{IF} = W_t L_t + \Pi_t + R_t D_{t-1}^e + R_t^{IF} N_{t-1}^{IF}.$$

The household is modeled as in Gertler and Karadi (2011) (GK11 from here on) with two additions: a time varying discount factor  $\beta_t$  and shares in investment funds  $N_t^{IF}$  as a savings alternative to deposits  $D_t^e$ . An increase in the discount factor results in the reduction of current consumption  $C_t$  and a subsequent drop in output demand and inflation, which lead to a reduction in the monetary policy rate, possibly reaching the ZLB. Each unit of labor  $L_t$  earns the real wage  $W_t$ .  $\Pi_t$  are profits from ownership of capital producers, retailers and financial intermediaries. The habit parameter is  $h$ ,  $\chi$  is the relative utility weight of labor and  $\varphi$  is the inverse Frisch elasticity of labor supply.

Household can save in deposits at commercial banks,  $D_t^e$ , and shares in investment funds,  $N_t^{IF}$ . I include fund shares to allow households to substitute towards higher yielding assets in response to monetary tightening. On the micro level, when a household wants to invest into shares, it enters the funding market with liquid assets  $D_t$  and randomly meets a potential investment fund. If the investment fund is a good fit regarding individual portfolio characteristics, they invest and form a match. On the macro level, this behavior is approximated by a search and matching mechanism: we only observe a fraction  $f_t$  of household savings  $D_t$  establish a match. The remaining savings are deposited in banks, with end-of-period deposits  $D_t^e = D_t(1 - f_t)$ . The fraction  $f_t$  is endogenously determined as explained in Section 4.3.2. Investment funds pay a state-contingent interest rate  $R_t^{IF}$ , which is above the risk-less real return  $R_t$  that banks pay on deposits. A fraction  $\theta_{IF}$  of households withdraws their existing fund investments every period, resulting in a law of motion for fund shareholdings:

$$N_t^{IF} = \theta_{IF} N_{t-1}^{IF} \xi_t^{IF} + f_t D_t. \quad (4.1)$$



Reinvested fund shares might be affected by  $\xi_t^{IF}$ , an autoregressive shock process of order one and unit mean. With  $\varrho_t$  denoting marginal utility of consumption and  $\mu_t$  denoting the additional value of being invested in fund shares, the first order conditions are given by

$$\text{Consumption } C_t : \quad \varrho_t = \frac{1}{C_t - hC_{t-1}} - \mathbb{E}_t \frac{\beta_{t+1}h}{C_{t+1} - hC_t}. \quad (4.2)$$

$$\text{Labor } L_t : \quad \chi L_t^\varphi = \varrho_t W_t. \quad (4.3)$$

$$\text{Deposits } D_t : \quad \varrho_t = (1 - f_t)\mathbb{E}_t \beta_{t+1} R_{t+1} \varrho_{t+1} + f_t(\mu_t + \varrho_t). \quad (4.4)$$

$$\text{Fund Shares } N_t^{IF} : \quad \mu_t + \varrho_t = \mathbb{E}_t \beta_{t+1} \{ R_{t+1}^{IF} \varrho_{t+1} + \mu_{t+1} \theta_{IF} \xi_{t+1}^{IF} \}. \quad (4.5)$$

The first order conditions for consumption and labor are standard. Equation (4.4) reduces to the commonly known Euler condition in the case that fund investments do not exist or have no additional value<sup>17</sup>, i.e., the household increases savings until the marginal utility of consumption today equals the discounted expected marginal utility of consumption tomorrow. If households can invest in fund shares, but their ability to find a match is constrained (i.e.,  $f_t < 1$ ), being invested in an investment fund is valuable (i.e.,  $\mu_t > 0$ ). The household therefore increases savings until the marginal utility of consumption today equals the *probability* of consuming tomorrow  $(1 - f_t)$  times its value (the discounted expected marginal utility of consumption tomorrow) plus the *probability* of investing in fund shares  $f_t$  times that value.

The value of investing in fund shares is given by Equation (4.5). The right-hand side can be rewritten to yield  $\mathbb{E}_t \beta_{t+1} \{ r_{t+1}^{IF} \varrho_{t+1} + (1 - \theta_{IF}) \varrho_{t+1} + \theta_{IF} (\varrho_{t+1} + \mu_{t+1}) \}$ . The first term denotes the per period net return  $r_{t+1}^{IF}$  from fund share investments that every investing household receives. The second term is the fraction of households that redeem their fund shares and use them for current period consumption. A fraction  $\theta_{IF}$  of households stays invested in fund shares and will reap the value of being invested one period hence, expressed in the last term.

### 4.3.2 Financial intermediaries

There are three types of intermediaries: commercial banks, investment funds and shadow banks. Commercial banks finance the real sector directly via loans and buy shadow bank commercial paper. Investment funds finance loans to the real sector and commercial paper in shadow banks via fund shares, which they sell to

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<sup>17</sup>Iff  $\mu_t = 0$ , Equation (4.4) holds for all  $f_t$ .

households. They are not able to leverage their operations with debt. Shadow banks use their funding to extend loans to the real sector.

### Commercial banks

There are infinitely many commercial banks in the economy, which are operated by members of households. Each commercial bank can make loans  $S_t^{CB}$  to the real sector that mature in one period and yield a return  $R_{t+1}^K$ , as in GK11. Following Meeks et al. (2014), every commercial bank can also extend credit to the shadow banking sector, which is called commercial paper. Commercial paper  $M_t^{CB}$  is different from regular loans, because it denotes a claim on a pool of loans managed by the shadow bank and yields a return  $R_{t+1}^{MCB}$ . The commercial bank funds these claims via net worth  $N_t^{CB}$  and deposits  $D_t$  that it receives from other households (excluding the household that it is managed by). The balance sheet of a commercial bank is then

$$Q_t S_t^{CB} + M_t^{CB} = N_t^{CB} + D_t \quad (4.6)$$

where  $Q_t$  denotes the price of physical capital. The commercial bank accumulates earnings net of the interest  $R_t$  that it pays out to depositors one period hence:

$$N_t^{CB} = R_{t+1}^K Q_t S_t^{CB} + R_{t+1}^{MCB} M_t^{CB} - R_{t+1} D_t. \quad (4.7)$$

Each commercial bank has a finite life time and exits the market with a probability  $\theta_{CB}$  each period. Once the commercial bank exits, it pays out accumulated lifetime earnings to the household whose member was its manager. The commercial bank therefore maximizes its expected terminal net worth  $V_t^{CB}$  by picking its loan portfolio and funding according to

$$V_t^{CB} = \max_{\{S_t^{CB}, M_t^{CB}, D_t\}_{i=0}^{\infty}} \mathbb{E}_0 \sum_{\tau=0}^{\infty} \left( \prod_{i=0}^{\tau} \beta_i \right) (1 - \theta_{CB}) \theta_{CB}^{\tau} \Lambda_{t,t+\tau} N_{t+\tau}^{CB}, \quad (4.8)$$

where the stochastic discount factor of the household is given by the marginal rate of substitution between consumption today and tomorrow  $\Lambda_{t,t+1}$  and the discount factor  $\beta_t$ . Since deposits only pay the risk free rate, a commercial bank has an incentive to keep leveraging up as long as it earns more than  $R_t$  on its credit claims. To motivate leverage endogenously, I introduce the incentive constraint

by GK11: Every period, a commercial bank can divert a fraction  $\lambda^{CB}$  of its credit claims, which leads to the termination of the commercial bank. Since in such a case depositors would lose their claims on the commercial bank, they force the commercial bank to limit its leverage in such a way that motivates the commercial bank to continue operations. A commercial bank is required to always maintain a value from continuing operations that is at least as high as the value it would gain from defaulting:

$$V_t^{CB} \geq \lambda^{CB}[Q_t S_t^{CB} + (1 - \lambda^{ABS})M_t^{CB}]. \quad (4.9)$$

A commercial bank can divert a larger fraction of its real sector loans, which are non-standardized, than of the commercial paper. Because commercial paper is a claim on a broad pool of loans, its standardization makes it more pledgeable. This is captured in the factor  $(1 - \lambda^{ABS})$ . As  $\lambda^{ABS}$  approaches 1, a commercial bank can reduce its funding constraint by shifting from outright lending to commercial paper, thereby evading leverage restrictions. This captures the regulatory arbitrage motive of off-balance sheet vehicles.

The solution to the commercial bank's problem is derived in Appendix C.1.1 and yields the balance sheet relation

$$Q_t S_t^{CB} + M_t^{CB}(1 - \lambda^{ABS}) = N_t^{CB} \phi_t^{CB} \quad (4.10)$$

with endogenous leverage  $\phi_t^{CB}$ .

Since a constant fraction  $\theta_{CB}$  of commercial banks exit each period, the remaining commercial banks have a net worth of

$$N_{et}^{CB} = \theta_{CB}(R_t^K Q_{t-1} S_{t-1}^{CB} + R_t^{MCB} M_{t-1}^{CB} - R_t D_{t-1}). \quad (4.11)$$

To make up for the outflow, households establish new commercial banks according to

$$N_{nt}^{CB} = \omega^{CB}(Q_t S_{t-1}^{CB} + M_{t-1}^{CB}) \quad (4.12)$$

with  $\omega^{CB}$  calibrated to pin down the steady state. The law of motion for commercial bank net worth is the combination of both existing and new net worth  $N_t^{CB} = N_{et}^{CB} \xi_t^{CB} + N_{nt}^{CB}$ . Existing commercial bank net worth may be affected by  $\xi_t^{CB}$ , an autoregressive shock process of order one and unit mean.

### Investment funds

In addition to commercial bank deposits, households may save in fund shares, which is a novel mechanism that I introduce into the GK11 framework. Fund shares offer higher returns on average in order to attract investments, but are state-contingent, since they are equity instruments. Infinitely many investment funds offer fund shares that differ on the micro level with regards to characteristics like investment style and fund management. Similarly, individual household preferences differ on the micro level with regard to the profile of an investment fund and individual portfolio preferences. Because of these idiosyncratic differences, households need to find a suitable fund, which takes time. Individual households and investment funds meet on the funding market at random and evaluate the potential for a match in isolation. I abstract from the mechanics on the micro level and approximate the behavior on the macro level via search and matching: in aggregate a fraction  $q_t$  of all investment funds searching for funding will find an investing household. In order to participate in the funding market, investment funds need to advertise their operations at a cost  $\kappa$  per advertisement  $v_t$ . After forming a match, an investment fund is able to invest into either loans to the real sector  $S_t^{IF}$  or the commercial paper of shadow banks  $M_t^{IF}$ .

In contrast to commercial banks, investment funds do not face the same incentive constraint problem, since they do not leverage their operations with debt or deposits. They lend out all acquired funding either to shadow banks or to the real economy. Given their funding, they maximize returns subject to constraints that prohibit them from investing more than a share  $\psi^{IF}$  of assets into commercial paper. Since commercial paper from shadow banks pays a higher return than loans to the real sector (see Equation (4.23)), investment funds generally invest into commercial paper up to their constraint  $\psi^{IF}$ .

Each period, investment funds pay out a return  $R_t^{IF}$  to their investing household. Some households will want to withdraw funding for consumption or alternative savings, while a fraction  $\theta_{IF}$  keeps their existing fund shares. The value of an investment fund that has formed a match is

$$V_t^{IF,M} = -R_t^{IF} + \psi^{IF} R_t^{MIF} + (1 - \psi^{IF}) R_t^K + \theta_{IF} \mathbb{E}_t \beta_{t+1} \Lambda_{t,t+1} V_{t+1}^{IF,M}, \quad (4.13)$$

where  $R_t^{MIF}$  is the return on commercial paper holdings of investment funds. Investment funds searching for funding have a value

$$V_t^{IF,S} = -\kappa + q_t \mathbb{E}_t \beta_{t+1} \Lambda_{t,t+1} V_{t+1}^{IF,M}. \quad (4.14)$$

Since operating an established investment fund is profitable, the value of operating an investment fund searching for funding may generally be profitable if the second term in Equation (4.14) is larger than the search cost  $\kappa$ . Additional potential investment funds searching for funding will therefore enter the funding market, which depresses the average fund filling rate  $q_t$ , until the value of a searching investment fund is zero. A Euler condition for the number of fund advertisements can be derived:

$$\frac{\kappa}{q_t} = \mathbb{E}_t \beta_{t+1} \Lambda_{t,t+1} \left\{ -R_t^{IF} + \psi^{IF} R_t^{MIF} + (1 - \psi^{IF}) R_t^K + \frac{\kappa}{q_{t+1}} \theta_{IF} \right\}. \quad (4.15)$$

New fund advertisements are posted until the cost of establishing an investment fund is equal to the return, which consists of the difference in interest income and expenses, as well as the value from not having to look for funding in the next period. The probability of finding a match is the number of realized matches  $m_t$  per advertisement<sup>18</sup>,

$$q_t = \frac{m_t}{v_t}. \quad (4.16)$$

The number of matches is determined by the number of fund advertisements as well as the amounts households want to save. Since investment funds offer a higher return than deposits pay, households always prefer to hold fund shares.<sup>19</sup> The number of matches therefore rises with the amount of household deposits and is determined via a Cobb-Douglas matching function

$$m_t = s D_t^\xi v_t^{1-\xi} \quad (4.17)$$

with matching efficiency  $s$  and matching elasticity  $\xi$ .

## Shadow banks

Shadow banks are financial intermediaries that channel funding from commercial banks and investment funds to the real sector. Commercial banks invest into shadow banks via commercial paper  $M_t^{CB}$ , which is standardized and therefore more pledgeable to the commercial bank creditors. Investment funds invest into the commercial paper of shadow banks  $M_t^{IF}$  because they offer a high return. Accumulated earnings in net worth  $N_t^{SB}$  retain the 'first loss' of securitized assets.

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<sup>18</sup>The rate at which households find a suitable investment is the investment finding rate  $f_t = m_t/D_t$ .

<sup>19</sup>The investment fund return is solved via Nash Bargaining and is derived in Appendix C.1.3.

The amount of real sector lending  $S_t^{SB}$  is

$$Q_t S_t^{SB} = M_t^{CB} + M_t^{IF} + N_t^{SB}. \quad (4.18)$$

Since they are leveraged, shadow banks maximize terminal expected net worth by choosing lending and funding sources according to

$$V_t^{SB} = \max_{\{S_t^{SB}, M_t^{CB}, M_t^{IF}\}_{t=0}^{\infty}} \mathbb{E}_0 \sum_{\tau=0}^{\infty} \left( \prod_{i=0}^{\tau} \beta_i \right) (1 - \theta_{SB}) \theta_{SB}^{\tau} \Lambda_{t,t+\tau} N_{t+\tau}^{SB}. \quad (4.19)$$

Retained earnings  $N_{t+1}^{SB}$  in a shadow bank are made up of the interest rate difference that they make on loans and what they pay on commercial paper by commercial banks and investment funds:

$$N_t^{SB} = R_t^K Q_t S_t^{SB} - R_t^{MIF} M_t^{IF} - R_t^{MCB} M_t^{CB}. \quad (4.20)$$

As in Meeks et al. (2014), shadow banks structure some of their liabilities to be extra safe, i.e., they pool their loans and attribute the safest returns to certain creditors. These creditors are commercial banks, which need pledgeable securities to circumvent their regulatory capital constraints. Only a fraction  $\psi^{CB}$  of all loans that shadow banks grant meet this standard. The amount of loans that can be financed via commercial paper held by commercial banks is therefore

$$M_t^{CB} \leq \psi^{CB} Q_t S_t^{SB}. \quad (4.21)$$

The solution to the shadow banks' problem is derived in Appendix C.1.2 and yields the balance sheet relation

$$Q_t S_t^{SB} = \frac{N_t^{SB} + M_t^{IF}}{1 - \psi^{CB}}. \quad (4.22)$$

Since some loans remain unsecuritized and non-pledgeable, a portion of the shadow bank balance sheets cannot be funded by commercial bank holdings of commercial paper. Demand by investment funds for commercial paper therefore increases the lending operations of shadow banks. In order to incentivize investment funds to hold commercial paper rather than grant loans themselves, shadow banks share the profit they receive from additional lending via Nash bargaining

according to

$$R_t^{MIF} = R_t^K + \zeta^{IF} \frac{\psi^{CB}}{1 - \psi^{CB}} (R_t^K - R_t^{MCB}), \quad (4.23)$$

where  $\zeta^{IF}$  is the bargaining power of the investment fund. Just like commercial banks and investment funds, a constant fraction  $\theta_{SB}$  of shadow banks exit each period. The remaining shadow banks have a net worth of

$$N_{et}^{SB} = \theta_{SB} (R_t^K Q_t S_t^{SB} - R_t^{MIF} M_t^{IF} - R_t^{MCB} M_t^{CB}). \quad (4.24)$$

To make up for the outflow, new shadow banks are established according to

$$N_{nt}^{SB} = \omega^{SB} Q_t S_{t-1}^{SB} \quad (4.25)$$

with  $\omega^{SB}$  calibrated to pin down the steady state. The law of motion for shadow bank net worth is the combination of both existing and new net worth  $N_t^{SB} = N_{et}^{SB} \xi_t^{SB} + N_{nt}^{SB}$ . Existing shadow bank net worth may be affected by  $\xi_t^{SB}$ , an autoregressive shock process of order one and unit mean.

### 4.3.3 Goods producers

The intermediaries are not productive by themselves and only derive profits from the return on loans to goods producers. Perfectly competitive goods producers manufacture intermediate goods and sell them to retailers at the relative intermediate output price  $P_{mt}$ . After production, non-depreciated capital is sold to capital producers and refurbished. Labor and capital for past production are remunerated and decisions for new production are taken: The firm maximizes profits by solving

$$\max_{\{K_{t+1}, L_t\}_{t=0}^{\infty}} \mathbb{E}_0 \sum_{\tau=0}^{\infty} \left( \prod_{i=0}^{\tau} \beta_i \right) \Lambda_{t,t+\tau} [P_{m\tau} Y_{\tau} + (Q_{\tau} - \delta) \xi_{\tau}^K K_{\tau} - W_{\tau} L_{\tau} - R_{k\tau} K_{\tau} Q_{\tau-1}]$$

with production output given by

$$Y_t = A_t (\xi_t^K K_t)^{\alpha} L_t^{1-\alpha} \quad (4.26)$$

where  $\alpha$  is the capital share,  $Q_t$  is the real price of capital,  $\delta$  is the depreciation rate,  $W_t$  are wages,  $A_t$  is a total factor productivity shock and  $\xi_t^K$  is a capital

quality shock. The first-order conditions are

$$R_t^K Q_t = P_{mt} \alpha \frac{Y_t}{K_t} + (Q_t - \delta) \xi_t^K \quad (4.27)$$

$$P_{mt} (1 - \alpha) \frac{Y_t}{L_t} = W_t. \quad (4.28)$$

Firms pay out ex post returns to capital as interest payments, resulting in no profits state by state. Since they pay the same interest rate  $R_t^K$  to all creditors, loans by different intermediaries are perfect substitutes and do not enter the maximization problem of the firm:

$$K_{t+1} = S_t^{CB} + S_t^{IF} + S_t^{SB}. \quad (4.29)$$

#### 4.3.4 Capital producers and retailers

Following GK11, capital producers buy leftover capital from goods producers which they refurbish, for which the price is unity. Units of new capital are made using input of final output and are then sold to goods producers at  $Q_t$ , which capital producers set by solving

$$\max_{I_{nt}} E_t \sum_{\tau=t}^{\infty} \beta_t^{\tau-t} \Lambda_{t,\tau} \left\{ (Q_\tau - 1) I_{n\tau} - f \left( \frac{I_{n\tau} + I_{SS}}{I_{n\tau-1} + I_{SS}} \right) (I_{n\tau} + I_{SS}) \right\}$$

with

$$I_{nt} \equiv I_t \iota_t - \delta \xi_t K_t. \quad (4.30)$$

Following the literature on the importance of marginal efficiency of investment (Justiniano et al., 2010), investment specific shocks  $\iota_t$  affect the transformation of gross investment into net investment. The functional form of  $f(\cdot)$  obeys  $f(1) = f'(1) = 0$  and  $f''(1) > 0$ .  $f(\cdot)$  determines capital adjustment costs with the steady state value for investments given by  $I_{SS}$ . The capital producer thus creates profits outside of the steady state. Households receive profits from sales of new capital at price  $Q_t$ , which is given by the first-order condition

$$Q_t = 1 + f(\cdot) + \frac{I_{nt} + I_{SS}}{I_{nt-1} + I_{SS}} f'(\cdot) - E_t \beta_t \Lambda_{t,t+1} \left( \frac{I_{nt+1} + I_{SS}}{I_{nt} + I_{SS}} \right)^2 f'(\cdot). \quad (4.31)$$

Retailers buy intermediate goods from goods producers at the relative intermediate output price  $P_{mt}$ . Final output is the CES composite of a continuum of



output by each retailer  $f$  with the elasticity of substitution  $\epsilon$ , given by

$$Y_t = \left[ \int_0^1 Y_{ft}^{\frac{\epsilon-1}{\epsilon}} df \right]^{\frac{\epsilon}{\epsilon-1}}.$$

Because users of final output minimize costs, we get

$$Y_{ft} = \left( \frac{P_{jt}}{P_t} \right)^{-\epsilon} Y_t$$

$$P_t = \left[ \int_0^1 P_{ft}^{1-\epsilon} df \right]^{\frac{1}{1-\epsilon}}.$$

Each retailer can reset prices with probability  $1 - \gamma$  each period. Retailers will otherwise index their prices to lagged inflation. The retailers then choose their reset price  $P_t^*$  optimally to solve

$$\max_{P_t^*} E_t \sum_{i=0}^{\infty} \gamma^i \beta_t^i \Lambda_{t,t+1} \left[ \frac{P_t^*}{P_{t+i}} \prod_{k=1}^i (1 + \pi_{t+k-1})^{\gamma_p} - P_{mt+i} \right] Y_{ft+i}.$$

The first-order condition is given by

$$E_t \sum_{i=0}^{\infty} \gamma^i \beta_t^i \Lambda_{t,t+1} \left[ \frac{P_t^*}{P_{t+i}} \prod_{k=1}^i (1 + \pi_{t+k-1})^{\gamma_p} - \frac{\epsilon}{\epsilon - 1} P_{mt+i} \right] Y_{ft+i} = 0. \quad (4.32)$$

The evolution of the price level is given by

$$P_t = [(1 - \gamma)(P_t^*)^{1-\epsilon} + \gamma(\Pi_{t-1}^{\gamma_p} P_{t-1})^{1-\epsilon}]^{1/(1-\epsilon)}. \quad (4.33)$$

### 4.3.5 Market clearing, resources and policy

The aggregate resource constraint is given by consumption, investment and adjustment costs

$$Y_t = C_t + I_t + f \left( \frac{I_{nt} + I_{SS}}{I_{nt-1} + I_{SS}} \right) (I_{nt} + I_{SS}). \quad (4.34)$$

Capital evolves according to

$$K_{t+1} = \xi_t^K K_t + I_{nt}, \quad (4.35)$$

i.e., an autoregressive capital quality shock  $\xi_t^K$  of order one captures the variability of capital productivity inherent in fixed capital. Following the literature on

the importance of marginal efficiency of investment (Justiniano et al., 2010), investment specific shocks  $\iota_t$  affect the transformation of gross investment into net investment. Gross investment  $I_{nt}$  is

$$I_{nt} \equiv I_t \iota_t - \delta \xi_t K_t. \quad (4.36)$$

Monetary policy is characterized by a Taylor rule. The nominal interest rate is given by  $i_t$ , with a steady state interest rate of  $i_{SS}$ , the steady state value of output given by  $Y_{SS}$ , an interest rate smoothing parameter  $\rho_i$ , the inflation coefficient  $\kappa_\pi$  and the output gap coefficient  $\kappa_y$ :

$$i_t = i_{t-1}^{\rho_i} \left[ i_{SS} (\pi_t)^{\kappa_\pi} \left( \frac{Y_t}{Y_{SS}} \right)^{\kappa_y} \right]^{1-\rho_i} \epsilon_t \quad (4.37)$$

The exogenous shock to monetary policy enters the nominal interest rate as  $\epsilon_t$ . The nominal interest rate has an effect on the economy through the Fisher relation

$$1 + i_t = R_{t+1} E_t(1 + \pi_{t+1}), \quad (4.38)$$

where  $E_t \pi_{t+1}$  is expected future net inflation.

## 4.4 Model specification and analysis

In this section, I first pin down the model parameterization via calibration and Bayesian estimation. Because I want to assess the model's ability to replicate business cycle statistics, I use a Bayesian estimation instead of minimizing the distance between empirical and theoretical IRFs as in Christiano et al. (2005). Distance minimization would be possible if empirical IRFs by the different intermediaries for other key macroeconomic disturbances were available. A Bayesian estimation allows a complementary analysis and can be understood as a cross validation for my empirical results: the model IRFs to monetary disturbances from the estimated parameters are comparable to the empirical IRFs in Chapter 2.

Next, I analyze how monetary policy shocks propagate through the economy for four different compositions of the financial system. Since only the financial sector is reconfigured, but fundamentals of the model economy are unaffected, real sector credit demand in steady state is unchanged. The baseline case is the financial system with commercial banks, shadow banks and investment funds, corresponding to the situation before the financial crisis of 2008. Since then,

shadow bank lending has declined and been replaced by commercial bank and investment fund lending, which is attributable to consolidation in the industry and new regulations. To show the effects of different financial sector compositions, I consider three cases, one in which shadow bank lending has been taken up by commercial banks, an alternative in which investment funds have taken up the credit demand, and one in which both sectors share previously intermediated credit by shadow banks. The different relative sizes of commercial banks to investment funds are due to changes in parameter values. The affected parameter values are the proportional transfer to the entering bankers  $\omega^{CB}$ , the proportional transfer to the entering shadow bankers  $\omega^{SB}$ , the fund's survival rate  $\theta_{IF}$ , the fund advertising cost  $\kappa$ , and the household bargaining power w.r.t. funds  $\zeta^{HH}$ . The model is solved via first order perturbation around the deterministic steady state.

#### 4.4.1 Parameterization

Several newly introduced parameters are calibrated to pre-crisis steady state values or directly follow from their economic counterparts. Parameters that govern the stochastic process as well as those that are not pinned down by steady state values and that do not have a direct economic counterpart are estimated. Most of the structural parameters present in GK11 are adopted here.

The pre-crisis economy includes a fully active shadow banking sector with a share of lending of approximately 35%, while commercial banks lent 40%, and investment funds lent the remaining 25% of credit.

The risk-free rate as measured by Shiller (1992) with updated values from his website is 3 percentage points per year. This translates into a quarterly risk-free rate of 75 basis points, i.e.,  $i_{SS} = .0075$  assuming zero inflation in steady state. In models featuring a conventional Euler equation this implies a higher discount factor than  $\beta = 0.99$ , which is used in this calibration. However, note that if the additional value from being invested in investment funds,  $\mu_t$ , is positive, and if search frictions guarantee that the finding rate  $f_t \in (0, 1)$ , then over-saving will result in a risk-free rate that is lower than  $\beta^{-1}$ .

The fraction of commercial bank assets invested in commercial paper by shadow banks is set at 30%, as indicated in bank call report data reported in Meeks et al. (2014). The corresponding fraction for investment fund assets is 40% pre-crisis as indicated by Flows of Funds data.

Symbol	Value	Description	Source
Households			
$\beta$	0.99	Steady state discount rate	Gertler and Karadi (2011)
$h$	0.815	Habit parameter	Gertler and Karadi (2011)
$\chi$	3.409	Relative utility weight of labor	Gertler and Karadi (2011)
$\varphi$	0.276	Inverse Frisch elasticity of labor supply	Gertler and Karadi (2011)
Financial Sectors			
$i_{SS}$	0.0075	Quarterly nominal rate	Shiller (1992)
$\psi^{CB}$	0.3	Fraction of commercial bank assets invested in commercial paper	Meeks et al. (2014)
$\psi^{IF}$	0.4	Fraction of investment fund assets invested in commercial paper	Flows of Funds
$\lambda^{ABS}$	1	Relative divertibility of ABS	Steady state
$\zeta^{IF}$	0.88	Fund bargaining power re shadow banks	Steady state
$\zeta^{HH}$	0.86	Household bargaining power w.r.t. funds	Steady state
$\omega^{CB}$	0.15	Proportional transfer to the entering bankers	Steady state
$\omega^{SB}$	0.04	Proportional transfer to the entering shadow bankers	Steady state
$s$	.32	Matching efficiency	Steady state
$\kappa$	.0007	Search cost	Steady state
Goods Producers			
$\alpha$	0.33	Effective capital share	Gertler and Karadi (2011)
$\delta$	0.025	Depreciation rate	Gertler and Karadi (2011)
Retail Firms			
$\epsilon$	4.167	Elasticity of substitution	Gertler and Karadi (2011)
$\gamma$	0.779	Probability of keeping prices fixed	Gertler and Karadi (2011)
$\gamma_p$	0.241	Price indexation	Gertler and Karadi (2011)
Government			
$\kappa_\pi$	1.5	Inflation coefficient of Taylor rule	Gertler and Karadi (2011)
$\kappa_y$	0.125	Output gap coefficient of Taylor rule	Gertler and Karadi (2011)

Table 4.1: Calibrated parameter values. *Note: 'steady state' refers to parameter values that directly follow from assumed steady state values. The steady state values are either the relative share of the financial sector or interest rate differentials.*

Remaining model parameters are chosen to imply a spread for the borrowing rate  $R_k - R_t$  of 79 bp, equal to the bank prime loan rate spread over the 3-month Treasury Bill rate between 2001 and 2004. A spread of 109 bp as proxied by Moody's Seasoned Aaa Corporate Bond Yield is chosen for the commercial paper rate that shadow banks pay to investment funds. I assume that shadow banks belong to commercial banks and therefore do not pay a higher interest rate  $R_t^{MCB}$  than  $R_t$ . This results in commercial paper held by commercial banks to be pledgable with a  $\lambda^{ABS} = 1$ , i.e., commercial banks cannot divert these assets. It follows from the steady state and parameter values that the bargaining power of investment funds vis-a-vis shadow banks  $\zeta^{IF}$  is then .88, since shadow banks need a buyer of remaining loan pools. The fraction of new equity that has to be injected into commercial bank and shadow bank equity, respectively, is  $\omega^{CB} = .15$  and  $\omega^{SB} = .04$ . The matching efficiency  $s$ , search costs  $\kappa$  and household bargaining power  $\zeta^{HH}$  follows from the steady state and parameter values. Table 4.1 shows the fixed structural parameter values and their source.

The remaining parameters, including those governing the shock processes, are estimated using Bayesian methods. Commercial banks, investment funds and shadow banks are defined as in Chapter 2: Commercial banks are US Depository Institutions and Credit Unions. Shadow banks are ABS Issuers, Security Brokers

Symbol	Name	Prior			Posterior		
		Type	Mean	Std. Dev.	Mean	L.B.	U.B.
Structural							
$\xi$	Matching elasticity	Beta	0.5	0.2	0.74	0.66	0.84
$\lambda^{CB}$	Commercial bank's divertible share	Beta	0.381	0.05	0.48	0.46	0.49
$\theta_{CB}$	Commercial bank's survival rate	Beta	0.75	0.05	0.63	0.57	0.68
$\theta_{IF}$	Investment fund's survival rate	Beta	0.75	0.05	0.74	0.68	0.80
$\theta_{SB}$	Shadow banker's survival rate	Beta	0.75	0.05	0.74	0.66	0.84
Persistence parameters							
$\rho_A$	TFP	Beta	0.5	0.2	0.68	0.54	0.85
$\rho_i$	Monetary Policy	Beta	0.5	0.2	0.61	0.55	0.68
$\rho_\xi$	Capital Quality	Beta	0.5	0.2	0.19	0.09	0.30
$\rho_{IS}$	Investment Efficiency	Beta	0.5	0.2	0.993	0.990	.998
$\rho_\beta$	Demand	Beta	0.5	0.2	0.84	0.77	0.90
$\rho_{CB}$	Commercial bank equity	Beta	0.5	0.2	0.25	0.11	0.37
$\rho_{IF}$	Investment fund equity	Beta	0.5	0.2	0.74	0.68	0.80
$\rho_{SB}$	Shadow bank equity	Beta	0.5	0.2	0.78	0.71	0.84
Std dev.							
$e_A$	TFP	Inverse Gamma	0.010	0.05	0.012	0.007	0.017
$e_i$	Monetary Policy	Inverse Gamma	0.010	0.05	0.003	0.002	0.004
$e_\xi$	Capital Quality	Inverse Gamma	0.010	0.05	0.012	0.011	0.014
$e_{IS}$	Investment Efficiency	Inverse Gamma	0.010	0.05	0.013	0.011	0.015
$e_\beta$	Demand	Inverse Gamma	0.010	0.05	0.004	0.003	0.006
$e_{CB}$	Commercial bank equity	Inverse Gamma	0.010	0.05	0.043	0.036	0.048
$e_{IF}$	Investment fund equity	Inverse Gamma	0.010	0.05	0.054	0.040	0.067
$e_{SB}$	Shadow bank equity	Inverse Gamma	0.010	0.05	0.200	0.166	0.226

Table 4.2: Priors and posteriors of estimated parameters. *Note: L.B. is the lower bound of the 90% highest posterior density interval. U.B. is the upper bound of the 90% highest posterior density interval.*

and Dealers, Finance Companies and Funding Corporations. Investment funds are Mutual Funds and Money Market Funds. As a measure of credit I include loans, bonds, consumer credit and commercial paper. The macroeconomic time series underlying the data for observables are: real GDP, the consumer price index, the federal funds rate, fixed capital, household consumption, and credit by commercial banks, investment funds and shadow banks (see Table C.1 in Appendix C.3 for details on the data sources). Since the model is expressed in log-deviations from steady state, for estimation purposes I take the log difference from the one-sided HP filtered trend (smoothing parameter is set to 1600) for all variables except inflation and the federal funds rate, which are depicted in Figure C.6 in Appendix C.3.3. The data have a quarterly frequency and range from 1984:I to 2006:IV.

The priors for all persistence parameters are relatively uninformative Beta distributions with a mean of 0.5 and a standard deviation of 0.2. The priors for the white noise processes on the innovations are Inverse Gamma distributions with means 0.01 standard deviations of 0.05. The shock processes are a priori independent. The prior distributions for the structural parameters are beta distributions. The interval for the matching elasticity allows all parameters between 0 and 1. The commercial bank's divertible share  $\lambda^{CB}$  is centered on the GK11 value of 0.381 and bound from below and bound from above to limit commercial bank

leverage. The intervals for survival rates are between (0.5, 1.0).

I run 2 Monte Carlo Markov Chains with 100.000 draws each over the full sample period. Convergence is reached after about 20.000 draws and I drop the first 50% of estimated values. Table 4.2 shows the results. The posteriors of the shock processes are informative (see Appendix C.3.3). In order to illuminate the dynamics of the matching friction, I conduct a robustness analysis of the matching elasticity  $\xi$  in Appendix C.2.

### 4.4.2 Response to a monetary policy shock

Figure 4.3 shows impulse response functions for key variables after unexpected monetary policy tightening for the case of i) the original GK11 economy, and ii) the baseline case with investment funds and shadow banks. Two additional cases describe what happens after elimination of the shadow banking system. In the case of iii) the loans previously held by shadow banks are now intermediated by commercial banks (bank dependent), and iv) the shadow bank loans are intermediated by funds (fund dependent). The third case corresponds to commercial banks granting 75% of all loans to the real economy, while the last case has commercial banks intermediating a total of 40% of credit. Investment funds intermediate the remaining share in the latter two cases.

First, consider the original GK11 economy. After an unexpected monetary tightening of about 100 basis points in the first period, interest rates on commercial bank deposits increase to encourage depositors to keep their savings with commercial banks instead of shifting them into other assets. Because households have a higher incentive to save, consumption drops. The reduction in consumption demand translates into lower output and a reduction in the demand for physical capital by firms, which also lowers the price for physical capital. Lower output and capital prices initially diminish the return on capital for the firm, see Equation (4.27). Since firms pass this return on as the borrowing cost to the intermediary, existing commercial bank profits are hit. In the second period, the borrowing rate increases, because the price for physical capital slowly rises from its initial low. Since the risk-free rate does not increase by as much as the borrowing rate, the external finance premium (EFP) rises. Equation (C.1.2) increases as the EFP rises, indicating gains from expanding assets for commercial banks. This means that the reduction in lending is not just due to the balance sheet channel, which would necessitate a drop in credit demand. Banks are unable to quickly raise equity and soliciting more deposits from households would cut into their margin. Credit to

the real sector therefore drops.

The baseline case features shadow banks and investment funds. After a monetary policy increase, the initial reaction in the economy is the same. However, commercial banks now have the ability to leverage up on their existing net wealth by increasing their investments into shadow banks, which lend on their behalf. At the same time, commercial banks face competition from investment funds, which increase the fund rate more aggressively than commercial banks increase the deposit rate. Households therefore substitute away from commercial bank deposits and into investment fund shares, which is consistent with empirical findings (Drechsler et al., 2016). Since many previously creditworthy borrowers were pushed out of the market, investment fund and shadow bank loans now replace some of the lost commercial bank credit. The bank lending channel is therefore reduced, because the financial sector substitutes away from bank deposits and into other funding options. This has a dampening effect on the fall in physical capital, which is reduced two thirds less compared to the GK11 economy with only commercial banks. The effect of the mitigated credit crunch is a less pronounced recession.

If the credit previously intermediated by shadow banks is now granted by commercial banks (the 'bank dependent' scenario), there is no room for outright regulatory capital arbitrage by commercial banks anymore. Commercial banks therefore cut back on credit after monetary policy tightening, opening up the possibility for investment funds to fill the excess credit demand. Investment funds do so by raising funding from households. Although investment funds increase lending by more than 3%, the decrease in commercial bank borrowing is hardly offset, resulting in a decrease in physical capital that is about twice as large as in the baseline case.

If instead investment funds intermediate the credit that was previously held by shadow banks (the 'fund dependent' scenario), capital reduction is comparable to the bank dependent scenario. The behavior is the result of different mechanisms, however. Shadow banks allow commercial banks to circumvent capital requirements and raise more deposits than households would be willing to lend to commercial banks themselves. In the case of large investment funds instead of shadow banks, any losses are passed on to the households owning the fund shares. New investments in investment funds still take place as households decrease consumption and allocate their resources to savings, especially fund shares.

The behavior of shadow bank lending following a monetary policy tightening is

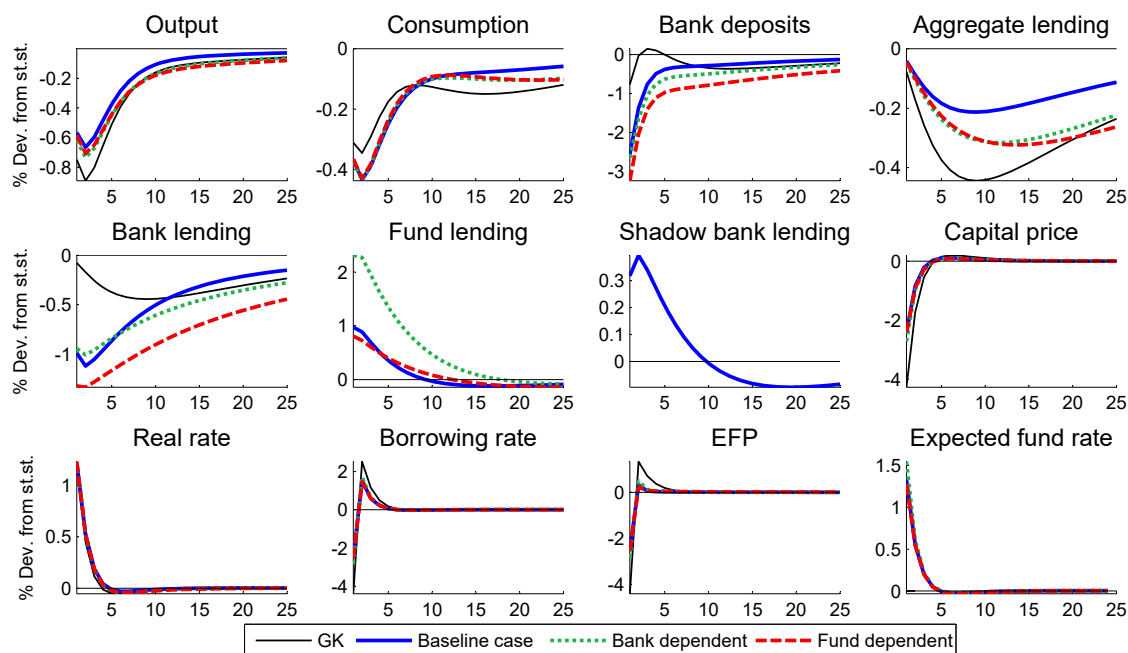


Figure 4.3: Model IRFs to monetary policy tightening of 100 basis points. *Note: The horizontal axis reports quarters since the shock. The vertical axis reports percentage deviations from the steady state (except for the interest rates and the EFP, which are reported in percentage points).*

consistent with the literature. A monetary tightening in the model induces a drop in commercial bank lending. In the BVAR in Chapter 2, commercial bank lending contracts in a hump shaped fashion over six years. The increase in investment fund and shadow bank loans in the empirical results are mirrored in the model reaction. A resulting negative 0.6% in GDP in the BVAR is exactly reached in the model. The difference is in timing. While the model reacts within the first couple of periods, the empirical IRFs have a longer transmission period. For the sake of tractability, I refrain from using any modeling devices that replicate empirical IRFs more closely.

Pescatori and Sole (2016), Nelson et al. (2015) and Igan et al. (2013) all show empirically that some shadow banks increase lending after monetary policy tightening, while commercial banks reduce lending. den Haan and Sterk (2011) show that both mortgages and consumption credit by shadow banks increase following an increase in the monetary policy rate. Finally, Altunbas et al. (2009) show that European banks with more securitization activities reduce their lending by less than non-securitizing banks after monetary tightening. European universal banks house both commercial banking and shadow banking activities within the same group structure. This finding is in line with understanding securitizing banks to



be less affected by monetary shocks because their shadow banking operations are larger, which insulates aggregate group lending behavior by increasing shadow bank lending following monetary policy tightening.

### 4.4.3 Business cycle effects

The benchmark economy with shadow banks compares well to second moments of some key variables in the data. Table 4.3 shows a close fit for GDP and intermediary credit standard deviations. Fixed capital is not as volatile as in the data, which might be due to labor being fully flexible and absorbing volatility in the production process. Model features like variable capital utilization and either monopolistically competitive labor unions or a search and matching process between firms and workers might fix this.

Variable	Data	Baseline	Shadow bank loans held by		
			Banks	Split 50/50	Funds
GDP	1.26	1.45	1.21	1.25	1.33
Inflation	.79	.56	.44	.44	.48
Consumption	.73	1.09	.91	.92	.95
Physical capital	4.28	2.57	2.32	2.36	2.42
Commercial bank loans	5.76	5.51	6.65	6.60	7.11
Investment fund loans	7.44	7.28	15.46	8.39	5.16
Shadow bank loans	5.86	5.72	—	—	—

Table 4.3: Second moments of data and model variants (all numbers in %). *Note:* Second moments for the data are calculated from cyclical variations around the one-sided HP filtered log data from 1984:I to 2006:IV. Second moments for the model variants are based on shock processes as estimated in Section 4.4.1.

If shadow banks are eliminated, the volatility of aggregate variables necessarily decreases because the stochastic process affecting shadow bank equity is eliminated. The three counterfactual scenarios can therefore be compared among each other but not to the baseline scenario. GDP and consumption are more volatile in fund-heavy economies because households earn a state-contingent return on fund shares instead of a non-contingent return on commercial bank deposits. Although this makes consumption smoothing more difficult, it insulates the financial sector from assuming losses. Passing on variable profits may increase financial stability by having the ultimate equity holders help absorb fundamental shocks.

Apart from a change in second moments, variable means may also change.<sup>20</sup>

<sup>20</sup>Deterministic steady states are studied, which ignore precautionary savings, to guarantee comparability among model variants.

Since the fundamentals in the economy are not affected by the composition of the financial system, means of real variables are unchanged. Instead, funding of the financial sector moves into the spotlight. In a more bank-dependent economy, commercial banks have to increase their deposit base by about 25%. This benefits households by increasing their total return from deposits by about 35%. Without shadow banks, however, regulatory arbitrage is not possible and commercial banks have to increase their equity holdings by about 80%. This increase in equity is arguably better for the stability of the financial sector, but it does beg the question whether commercial banks would be able to raise the required capital following a financial crisis.

In the case that the economy becomes more fund-dependent, commercial bank deposits diminish. Instead, fund share holdings are increased by about 40%, while commercial bank equity stays the same. This increases total fund returns to households, while decreasing total returns to deposits. The net result is a slightly higher total return for households from financial assets compared to the baseline case, and a 5 percentage point increase above the bank-dependent scenario. The reason for this is that fund returns include a rent from the surplus of the funding match (see Appendix C.1.3).

## **4.5 Shadow bank regulation at the zero lower bound**

Before the financial crisis, the shadow banking system contributed about 35% of credit to the real economy. This share has dropped significantly since 2007 (see Figure C.3 in Appendix C.3). The shadow banking system has been the explicit focus of financial regulation in many countries around the world (see Financial Stability Board, 2016). Although no consensus has emerged, the dominant principle has been to bring credit intermediation out of the shadows. This means that shadow banks would either be differently regulated, or that they cease to exist and that the credit demand they previously intermediated would be assumed by other institutions. In effect, the options then are to regulate this credit demand like commercial bank credit, like investment funds, or a combination of those. At the same time, many of those same economies have been plagued by the ZLB on nominal interest rates. Central banks and governments are actively trying to escape the ZLB with different measures and varying success. This section studies how an economy behaves under different financial intermediary regimes during a prolonged time at the ZLB.

### 4.5.1 Technical specifications

A ZLB on nominal interest rates means that the central bank cannot set the net monetary policy rate below 0, which amounts to an occasionally binding constraint. Formally, this changes the Taylor rule, equation (4.37), to

$$i_t = \begin{cases} i_{t-1}^{\rho_i} \left[ i_{SS}(\pi_t)^{\kappa_\pi} \left( \frac{Y_t}{Y_{SS}} \right)^{\kappa_y} \right]^{1-\rho_i} \epsilon_t & , \text{ if } i_t > 0 \\ 0 & , \text{ otherwise.} \end{cases} \quad (4.39)$$

Since this induces non-linearities in the policy functions of economic agents, I use the method by Guerrieri and Iacoviello (2015) to find an approximated solution. The utilized OccBin toolbox considers an economy with two regimes, the "reference" regime in which the monetary policy rate follows a linearized Taylor rule and the "alternative" regime in which it is constant at zero. A piecewise-linear solution is found by considering the reference regime where the constraint is slack until the monetary policy rate reaches its lower bound. The regime then switches to the alternative where the constraint is binding until the reference regime indicates a move away from the constraint. Guerrieri and Iacoviello (2015) show that the piecewise-linear solution from their toolbox is comparable to a global solution for the ZLB case in the Smets and Wouters (2007) model. The Smets and Wouters model is the baseline framework for the Gertler and Karadi set-up, which I use here.

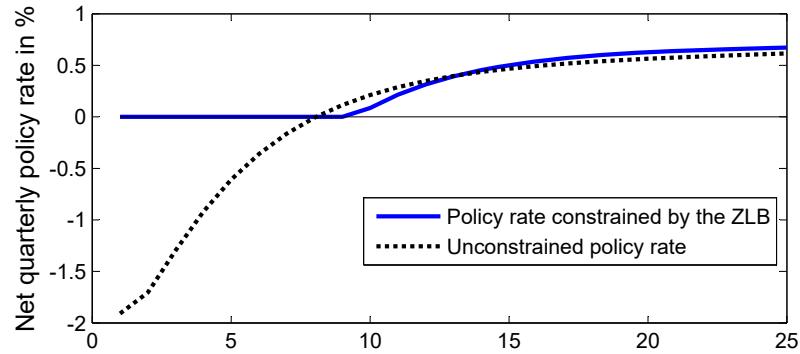


Figure 4.4: Monetary policy path after negative demand shocks. *Note: The horizontal axis shows periods in quarters. The vertical axis is the net policy rate in annualized percentage points.*

A common way of analyzing the ZLB in theoretical models is to assume preference shocks<sup>21</sup> that elicit households to forego consumption today, see also Chris-

<sup>21</sup>Although the financial crisis of 2008 has its roots in the financial sector, a negative household demand shock captures the reaction to the destruction in household wealth that followed the

tiano et al. (2011) and Fernandez-Villaverde et al. (2015). Following this literature, I turn monetary policy smoothing off ( $\rho_i = 0$ ). In addition, I increase price rigidity to  $\gamma = 0.9$  and the Taylor rule coefficient for inflation to  $\kappa_\pi = 2.5$  as in Guerrieri and Iacoviello (2015). These changes limit the use of disinflation in order to escape the ZLB, which is in line with the current ZLB experience. Following the drop in demand, output and inflation fall. This prompts the monetary authority to lower the policy rate until it reaches zero.

The discount factor receives an innovation of  $\epsilon_\beta = 0.06$ , which decreases output by 4 percent during a ZLB episode, comparable to the drop in GDP in 2008 (see the cyclical variation in the GDP panel in 2009, Figure C.6 in Appendix C.3.3). The monetary authority reacts by lowering the policy rate, see Figure 4.4. An unconstrained policy stimulates investment by lowering borrowing costs, while also limiting household incentives to save. With a ZLB, the economy never receives this feedback and is instead stuck with a policy rate that is above its desired level.

Without the ZLB (black, dotted line), the quarterly policy rate initially drops to  $-1.8\%$  and remains negative for 8 quarters. Evaluating the quantitative fit of the reaction of unconstrained monetary policy is difficult because the Federal Open Market Committee (the monetary policy-making body of the Federal Reserve System) does not publish this data. Shadow rates as in Wu and Xia (2016); Krippner (2014); Lombardi and Zhu (2014) estimate policy rates that include the effects of other monetary accommodations and can act as a proxy. They are not the same as the *desired* policy and report quarterly rates as low as  $-1.25\%$ . This falls short of my model estimate, which is plausible given that the monetary authority in the unconstrained case achieves better stabilization (GDP drops by less than 1%).

### 4.5.2 Implications of replacing credit supply of shadow banks with credit supply of banks or funds

As explained in Section 4.4.2, bank credit decreases in response to monetary policy tightening due to the bank lending channel. However, shadow banks and investment funds increase lending. This behavior suggests that a policy rate above its natural level is conducive for NBFIs lending. Furthermore, it begs the question whether an economy with a larger share of aggregate credit coming from NBFIs

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drop in real estate values as well as the effects on household asset holdings in financial firms. If real estate wealth or mortgages were explicitly modeled, I could include a shock that lowers their value.

	Commercial banks	Investment funds	Shadow banks
i) Baseline case	40%	25%	35%
ii) Bank dependent case	75%	25%	–
iii) Fund dependent case	40%	60%	–

Table 4.4: Loan shares under different regulatory scenarios. *Note: The baseline case corresponds roughly to the shares of fixed income securities to the real sector in 2006. The bank dependent case refers to credit previously held by shadow banks to be intermediated by commercial banks. The fund dependent case assumes that all shadow bank credit is lent out by investment funds.*

may be less affected by a policy rate above its natural level. To answer this question, I analyze the response of the economy under three different scenarios: i) the baseline case with commercial banks, investment funds and shadow banks under the baseline parameterization; ii) the bank dependent case in which shadow banks are eliminated and the excess credit demand is taken up by commercial banks; and iii) the fund dependent case in which investment funds take on all of the loans previously intermediated by shadow banks. The baseline case is 'historical' in the sense that a large shadow banking system was intact prior to the crisis but has decreased markedly since. Shadow banks are likely to be more heavily regulated going forward. The last case assumes that several regulatory proposals that favor the capital market based credit system over the bank based one are enacted. This approach is currently being taken in Europe with the Capital Markets Union expected to allow NBFIs to increase their market share. Table 4.4 summarizes the loan shares for the three cases.

Figure 4.5 shows the evolution of key variables for the case in which the ZLB is binding (left hand side) and in which the policy rate is unconstrained (right hand side). Consider the baseline case with a shadow banking system intact (blue, solid line) with an unconstrained monetary policy. An increase in the household discount factor induces households to consume less and save more. To counter this development, monetary policy is reduced, thereby lowering the real rate, which stimulates investments. The additional credit is supplied by banks, which face reduced financing costs via deposits. A deep recession can be avoided by quickly lowering the policy rate.

Next, consider the baseline case under the ZLB (blue line in the left hand panels). While the economy suffers from inadequate demand, the policy rate is bound at zero. The real rate can therefore not fall enough to stimulate investment and in fact rises, since the drop in demand results in deflation. This causes commercial

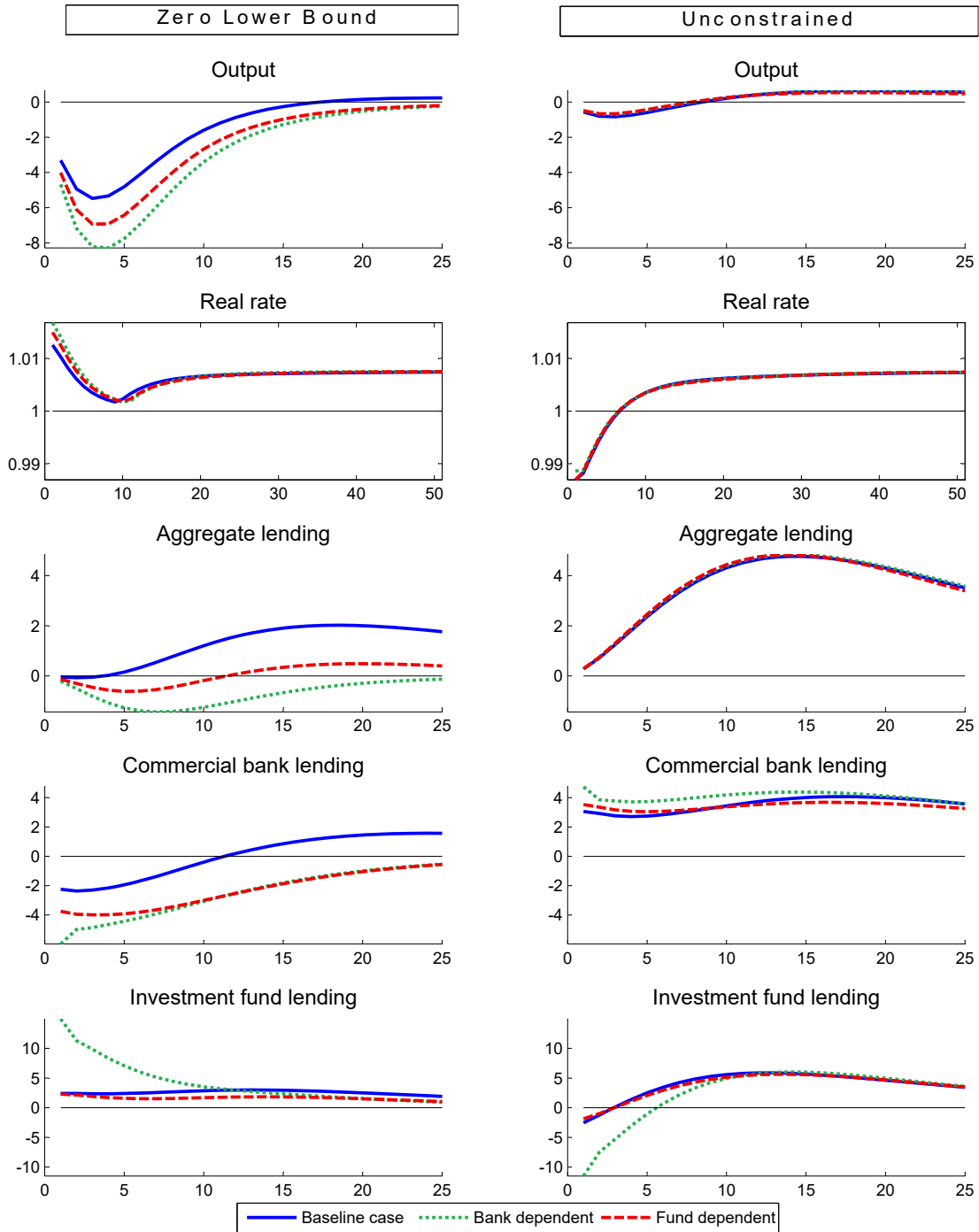


Figure 4.5: Paths of key variables after a prolonged time at the ZLB for different regulatory regimes. *Note: The left panels show paths for key variables under the ZLB constraint. The right hand panels show paths for unconstrained economies. Horizontal axes show periods in quarters, vertical axes are percentage deviations from steady state, except for the real rate which is reported in levels.*

banks to decrease lending, because their funding supply decreases. As a result, only the most creditworthy firms (i.e., those with a high marginal return on capital) can keep borrowing. Although some credit is channeled via shadow banks, and investment funds receive an inflow in funding because they pay a higher expected return than deposits, credit does not increase enough to counter the drop in demand. A negative 4% drop in output follows, which is comparable to the recession following the recent financial crisis. This scenario is no longer applicable, since the financial crisis caused many shadow banks to go out of business, thereby eliminating the opportunity for commercial banks to channel funds off their own balance sheets.

Credit previously held by shadow banks is now taken on by commercial banks or investment funds. The bank dependent case (green, dotted line) illustrates this scenario. Since commercial banks' supply of funds is decreasing, they are reluctant to grant credit and they cut back on lending. Investment funds receive an inflow in funding, as households earn more from fund shares than commercial bank deposits. Since investment funds pass on the lower profits from depressed borrowing rates, they still profit from additional lending and therefore increase credit intermediation. Although additional investment fund lending counteracts the reduction in commercial bank lending somewhat, it is not sufficient to generate enough investment to stop the recession. The economy unconstrained by a ZLB does not suffer such a sharp recession, as commercial banks do not scale back lending as much due to the cheap refinancing via negative real rates. Following the ZLB episode, commercial banks slowly reverse credit intermediation back to steady state levels. At the same time, investment funds reduce lending as the policy rate is back to its natural level.

Finally, consider the case in which investment funds provide the largest share of credit (red, dashed line). Again commercial bank lending is reduced, following a reduction in funding. However, lending by investment funds increases sufficiently to motivate enough investments for a prolonged period. The reason for this is that in steady state households are less invested in deposits and the rebalancing into fund shares is less pronounced. This reduces the impact of the lending channel and allows more firms to invest into capital. These investments keep GDP from dropping as much as in the bank dependent scenario and allow for a less severe recession compared to the bank dependent case.

### 4.5.3 A demand shock at the ZLB initiates the bank lending channel

The more favorable dynamics of a less bank-based credit system during a ZLB episode can be explained via the bank lending channel of monetary policy. In order to better understand this result, consider the Euler equation (4.4) with the value of fund investments, Equation (4.5), inserted in the last term on the right hand side:

$$\varrho_t = (1 - f_t)\mathbb{E}_t\beta_{t+1}R_{t+1}\varrho_{t+1} + f_t\mathbb{E}_t\beta_{t+1}\{R_{t+1}^{IF}\varrho_{t+1} + \mu_{t+1}\theta_{IF}\xi_{t+1}^{IF}\}. \quad (4.40)$$

The economic disturbance that hits the economy in this exploration is a large demand shock that increases the household discount factor. Households reduce current period consumption until the marginal utility of consumption rises to equal the right hand side of the Euler condition. To limit incentives for households to save, the monetary authority reduces the policy rate, lowering the real rate  $R_{t+1}$  in an economy unconstrained by the ZLB. This has two effects: the marginal utility of current consumption on the left hand side does not have to rise as much so current consumption is not reduced as much. In addition, the lower real rate results in additional investments. Consequently, aggregate demand only suffers slightly.

If the economy is constrained by the ZLB, the policy rate cannot counter the increase in the first term on the right hand side of the Euler condition. Current period consumption has to drop further to satisfy a higher marginal utility of consumption. The second component of aggregate demand, investment, does not rise enough to counter this development, since the real interest rate remains above the unconstrained level. Because of deflation, the real rate even rises. A much more pronounced recession is the result.

The increase in the real rate is likewise the reason for the bank lending channel becoming operational in the case of a demand shock at the ZLB. This can be seen by taking the differences of the variable responses in case of the ZLB versus the unconstrained paths, which removes the effects purely due to the demand shock. Figure 4.6 shows these IRFs. The ‘shock’ in this diagram is due to the monetary authority’s inability to lower the policy rate by an additional two percentage points after the demand shock hits. The reactions of most other variables are then similar to the case of monetary policy tightening in Section 4.4.2.

Now consider the second term in the right hand side of the Euler condition.



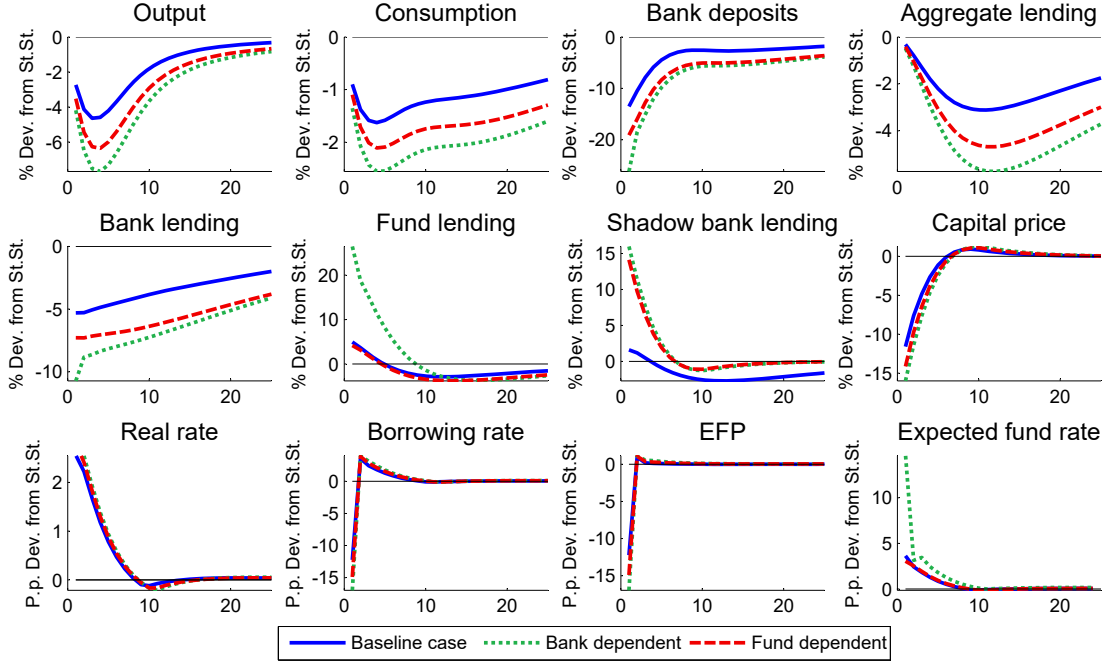


Figure 4.6: Differences in reactions of the ZLB and unconstrained models to a demand shock. *Note: The horizontal axis reports quarters since the shock. The vertical axis reports percentage deviations from the steady state (except for the interest rates and the EFP, which are reported in percentage point deviations).*

If households can easily find investment funds as an alternative to deposits, the fund finding rate  $f_t$  is higher and the weight on the first term on the right hand side is smaller. The inability of the monetary authority to lower the policy rate does not affect the economy as much. Instead, the focus shifts to the reaction of variables in the second term, the fund rate  $R_{t+1}^{IF}$  and the additional value from being invested in fund shares  $\mu_{t+1}$ . In a bank-dependent credit economy, both variables increase strongly following the activation of the bank lending channel, because funds are able to strongly raise the fund rate they pay on shares. In a fund-dependent economy, there are already many funds in operation and many households invested in them. Therefore funds have a reduced incentive to increase the fund rate.<sup>22</sup>

The fund-based economy can be interpreted as one in which households have already exhausted most options for higher yielding, non-depository assets. The activation of the bank lending channel then has little effect on the funding supply of the economy. Alternatively, in a bank based economy, households rebalance their portfolios towards higher yielding assets, which increases the effectiveness of

<sup>22</sup>Additional households on the funding market are a positive externality for searching funds, but seen as congestion from the perspective of searching households (Petrongolo and Pissarides, 2001).

the bank lending channel. The reduction in credit is not desirable while the policy rate is at the ZLB. This can be countered by lowering the effectiveness of the bank lending channel through more non-depository sources of funding.

## **4.6 Conclusions**

Shadow banking in the sense of regulatory arbitrage as treated here will likely be strongly contained in the regulatory overhaul currently discussed in various countries. Since the void will have to be filled with credit coming from different sources, this paper suggests some business cycle implications for credit systems that are more equity versus deposit based. If commercial banks pick up the credit previously supplied by shadow banks, consumption volatility is reduced. If instead investment funds are taking up the additional credit demand, consumption is more volatile, resulting from the state-contingent return that fund investments deliver. Allocating losses to the ultimate equity holders instead of concentrating them in the financial sector may have additional benefits for financial stability that go beyond the scope of this paper.

A key advantage of having a fund-dependent financial sector comes from the behavior at the ZLB. Investment funds benefit from a higher real rate as they experience a funding inflow from savers in contrast to commercial banks. This inflow is translated into more loans that partially make up for the reduction in commercial bank credit. The effectiveness of the bank lending channel is therefore reduced, which is beneficial during a ZLB episode. Although a recession cannot be avoided, the drop in GDP is not as deep, and the return to steady state levels occurs more quickly when the credit economy is funded less by deposits and more by fund shares.

The paper therefore supports current plans in the European Union to increase the size of the market based financial system on the basis of an increased resilience to ZLB issues. However, in order to make more comprehensive suggestions, a detailed analysis based on European data and financial system configurations would need to follow. The same argument that favors fund based credit systems during ZLB episodes might speak in favor of a bank based system outside the ZLB. The bank lending channel is more effective in a more deposit based credit system, i.e., credit will react more strongly to monetary policy. This may be desirable, if the monetary authority wants to stave off a potential recession by lowering the policy rate and stimulating credit. Whether one credit system dominates the other therefore depends on the frequency at which monetary policy is constrained by

the ZLB.

There are several directions along which this analysis may be extended. This includes modeling explicit regulatory tools, like leverage restrictions, liquidity requirements or macroprudential instruments to allow for more nuanced policy recommendations. Also, the effectiveness of fiscal measures might vary depending on the share of equity and deposit funding of the credit economy. On a related note, unconventional monetary policy in the form of large scale asset purchases or forward guidance is likely to have varying impacts on and interactions with the different intermediaries, which changes their effectiveness depending on the credit system configuration.



## APPENDIX TO CHAPTER 2

## A.1 Full BVARs

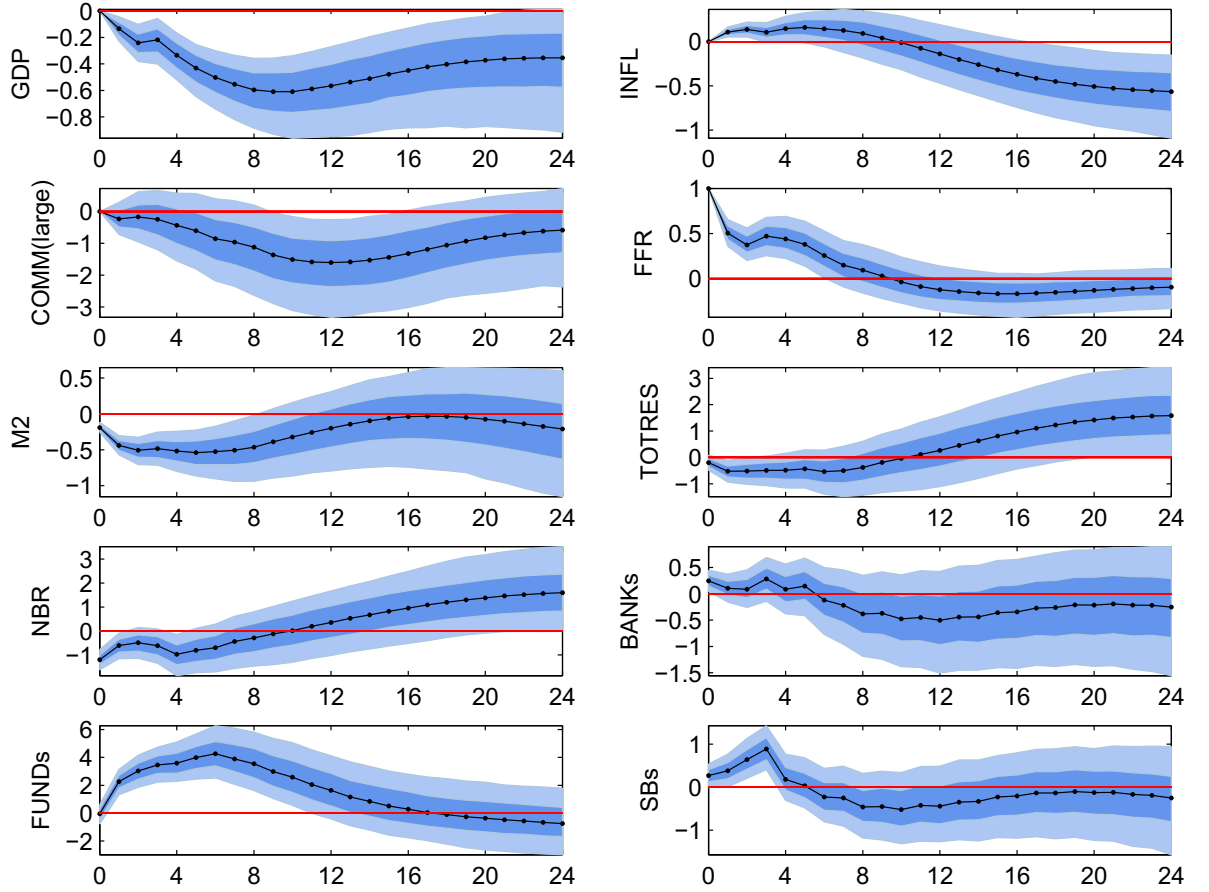


Figure A.1: Responses of fixed income credit holdings by intermediaries to a contractionary monetary policy shock. *Note: This is the baseline specification.*

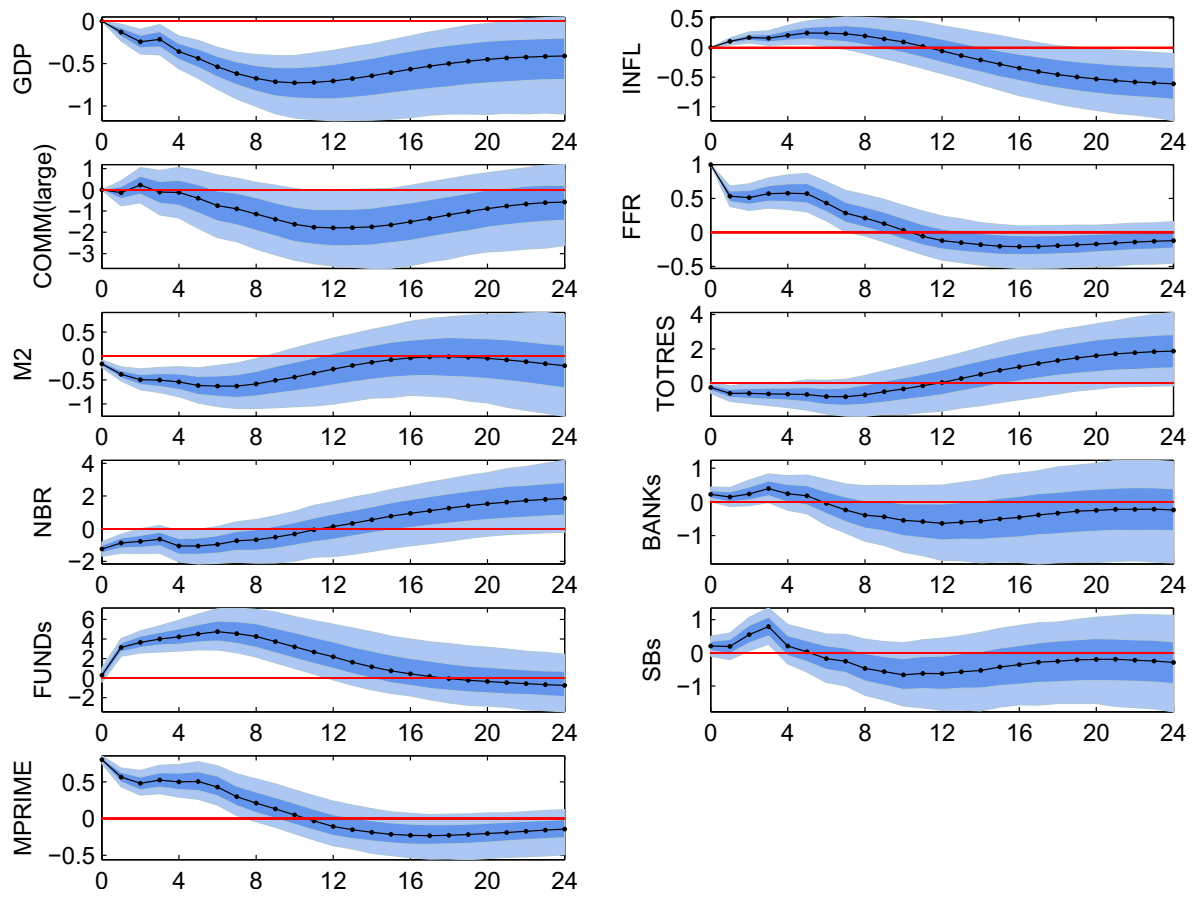


Figure A.2: Responses of bank credit price and volume.

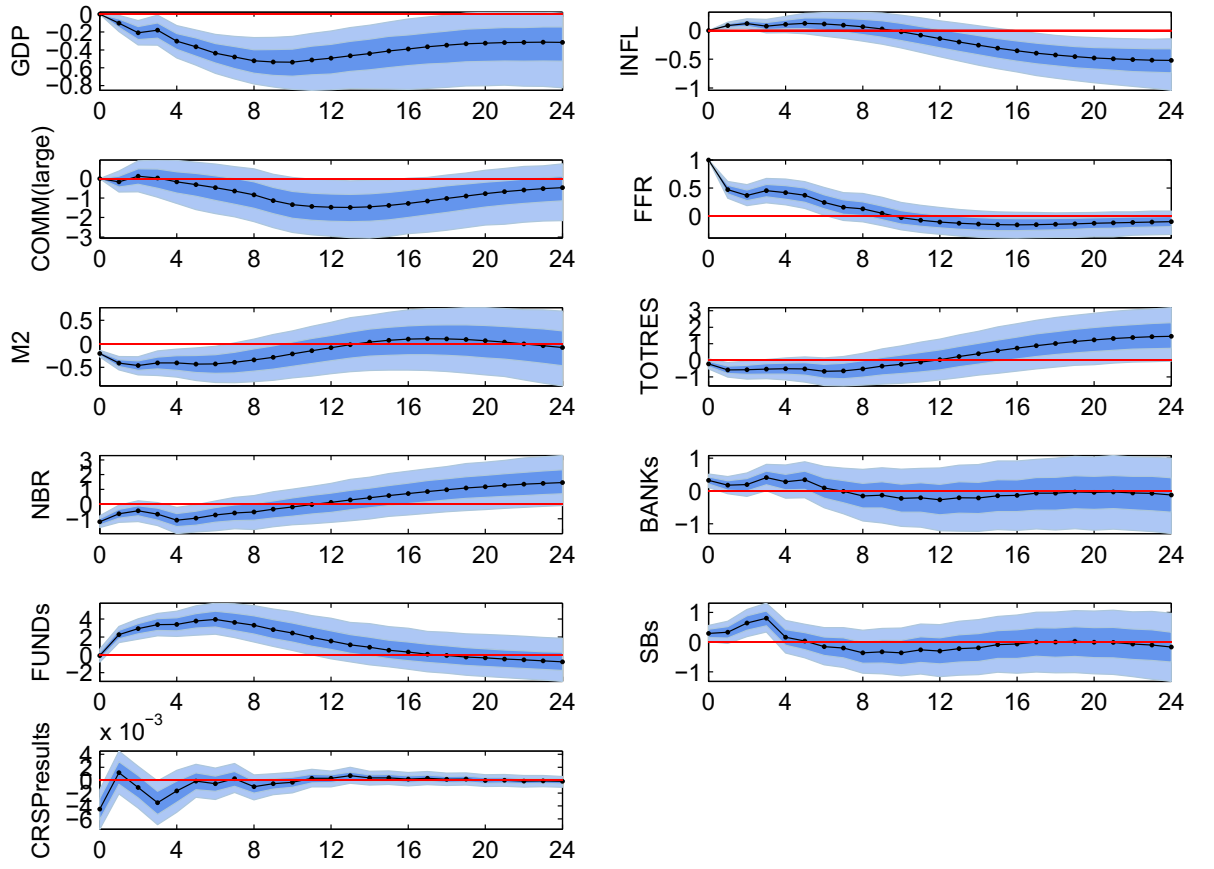


Figure A.3: Responses of fund credit price and volume.

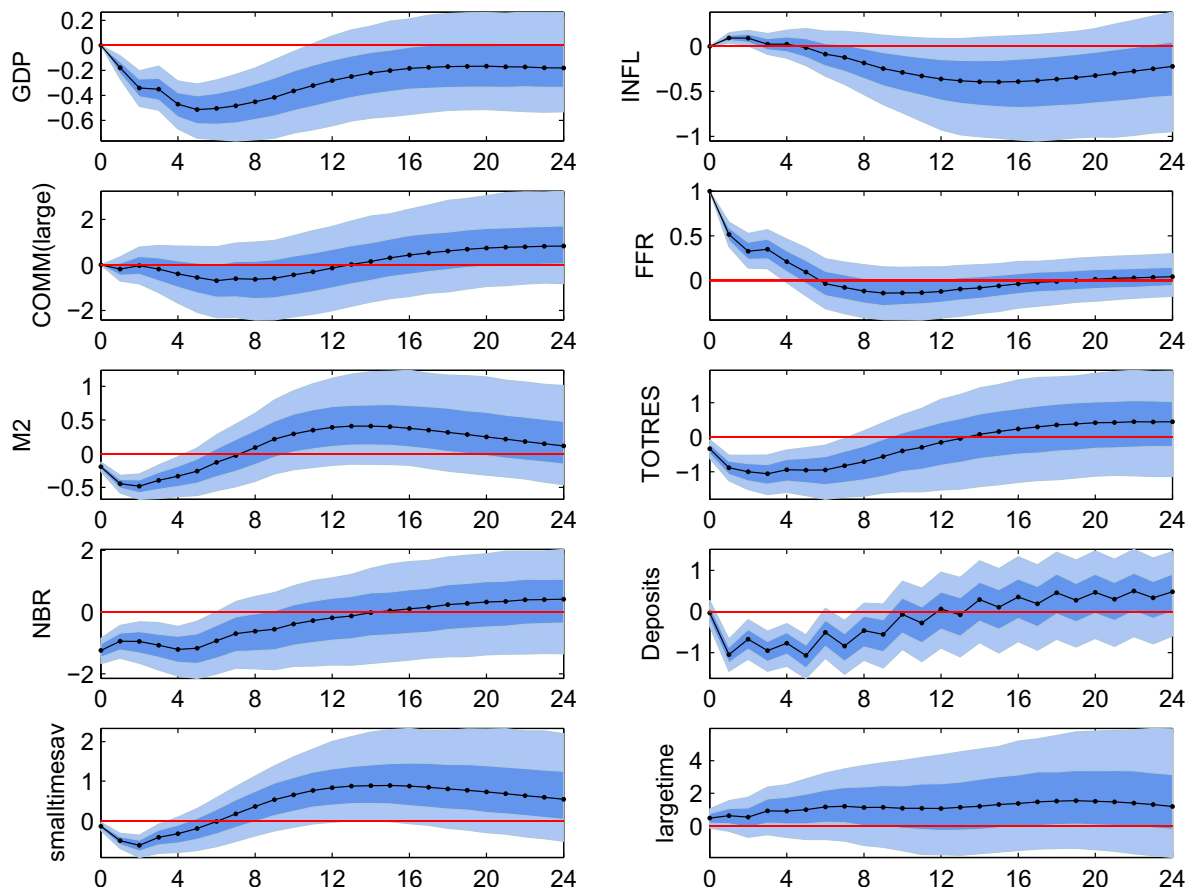


Figure A.4: Responses of bank funding.



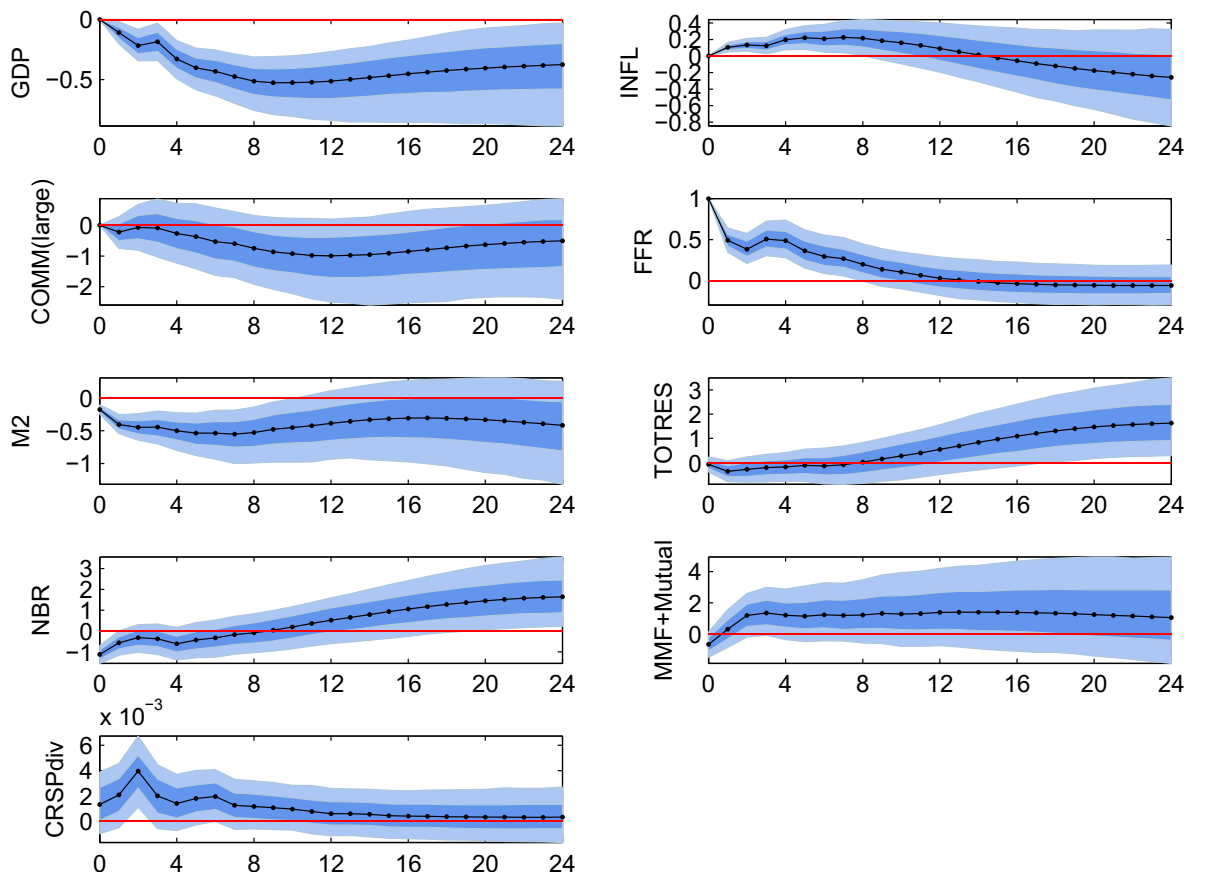


Figure A.5: Responses of investment fund shareholdings.

## A.2 Data Sources

Variables	Description	Source
Aggregate Output $Y_t$	Real Gross Domestic Product, USD, not s.a.	Stock and Watson (2012)
M2 Money Supply	M2SL, USD, not s.a.	Stock and Watson (2012)
Inflation $\pi_t$	Consumer Price Index For All Urban Consumers: All Items	Stock and Watson (2012)
Index of sensitive materials prices		Stock and Watson (2012)
Federal Funds Rate $i_t$	Effective Federal Funds Rate	Stock and Watson (2012)
Bank Loans $S_t$	Fixed income credit to the real sector <sup>1</sup> of U.S.-chartered depository institutions and credit unions, USD, not s.a.	U.S. FoF
Investment Fund Loans $S_t^F$	Fixed income credit to the real sector of Money Market Mutual Funds, Mutual Funds, USD, not s.a.	U.S. FoF
Shadow bank Loans $S_t^S$	Fixed income credit to the real sector of ABS Issuers, Financing Companies, Funding Corporations, Security Brokers and Dealers, USD, not s.a.	U.S. FoF
Investment fund rate	averages of total returns per share; equity of each fund	CRSP Database
Price of bank credit	Bank Prime Loan Rate, Percent, Monthly, Not Seasonally Adjusted	U.S. FoF
Bank funding	Checkable deposits; small and large time and savings deposits	U.S. FoF
Shareholdings in investment funds	Household shareholdings in money market funds and mutual funds	U.S. FoF

Table A.1: Data sources and definitions.

## APPENDIX TO CHAPTER 3

### B.1 Appendix: Full Model Equations

#### B.1.1 Original BGG

Resource constraint

$$Y_t = C_t + I_t + G_t + C_t^e + \mu \int_0^{\bar{\omega}_t} \omega dF(\omega) R_t^k Q_{t-1} K_t \quad (\text{B.1.1})$$

Consumption Euler relation

$$\frac{1}{C_t} = \beta \mathbb{E}_t \frac{R_{t+1}}{C_{t+1}} \quad (\text{B.1.2})$$

Entrepreneurial consumption

$$C_t^e = (1 - \gamma) N_t \quad (\text{B.1.3})$$

Supply of investment finance [BGG (4.5)]

$$\mathbb{E}_t R_{t+1}^k = s \left( \frac{N_{t+1}}{Q_t K_{t+1}} \right) R_{t+1} \quad (\text{B.1.4})$$

Expected gross return to capital [BGG (4.4)]

$$\mathbb{E}_t R_{t+1}^k = \mathbb{E}_t \left\{ \frac{\frac{1}{X_{t+1}} \frac{\alpha Y_{t+1}}{K_{t+1}} + Q_{t+1} (1 - \delta)}{Q_t} \right\} \quad (\text{B.1.5})$$

Price of capital [BGG (4.3)]

$$Q_t = \left[ \Phi' \left( \frac{I_t}{K_t} \right) \right]^{-1} \quad (\text{B.1.6})$$

Production function [BGG (4.1)]

$$Y_t = A_t K_t^\alpha L_t^{1-\alpha} \quad (\text{B.1.7})$$

Labor market equilibrium [BGG (4.11) and BGG Appendix (B.4)]

$$(1 - \alpha)\Omega \frac{Y_t}{H_t} \frac{1}{C_t} = X_t \xi \frac{1}{1 - H_t} \quad (\text{B.1.8})$$

Phillips curve

$$\pi_t = E_{t-1}\{\kappa(-x_t) + \beta\pi_{t+1}\} \quad (\text{B.1.9})$$

Evolution of capital [BGG (4.2)]

$$K_{t+1} = \Phi\left(\frac{I_t}{K_t}\right) K_t + (1 - \delta)K_t \quad (\text{B.1.10})$$

Evolution of net worth [BGG (4.13)]

$$N_{t+1} = \gamma \left[ R_t^k Q_{t-1} K_t - \left( R_t + \frac{\mu \int_0^{\bar{\omega}_t} \omega dF(\omega) R_t^k Q_{t-1} K_t}{Q_{t-1} K_t - N_t} \right) (Q_{t-1} K_t - N_t) \right] + W_t^e \quad (\text{B.1.11})$$

Entrepreneurial wage [BGG (4.12)] and  $H_t^e$  normalized to 1

$$(1 - \alpha)(1 - \Omega)Y_t/H_t^e = X_t W_t^e \quad (\text{B.1.12})$$

Gross nominal interest rate [BGG appendix]

$$1 + i_{t+1} = R_{t+1} \pi_{t+1} \quad (\text{B.1.13})$$

Deposits at intermediaries [BGG appendix and BGG (3.2)]

$$D_{t+1} = B_{t+1} = Q_t K_{t+1} - N_{t+1} \quad (\text{B.1.14})$$

### B.1.2 Firm entry extension

Equation (B.1.11) is replaced by Equation (E.4):

$$N_{t+1} = \gamma \left[ R_t^k Q_{t-1} K_t - \left( R_t + \frac{\mu \int_0^{\bar{\omega}_t} \omega dF(\omega) R_t^k Q_{t-1} K_t}{Q_{t-1} K_t - N_t} \right) (Q_{t-1} K_t - N_t) \right] + f_t D_{t+1}. \quad (\text{B.1.15})$$

Probability that a household will find an investment

$$f_t = s \left( \frac{v_t}{D_{t+1}} \right)^{1-\eta} \quad (\text{B.1.16})$$

Effective deposits that have not been invested in equity

$$D_{t+1}^e = (1 - f_t) D_{t+1} \quad (\text{B.1.17})$$

Available deposits at intermediaries, Equation (B.1.14) , becomes

$$D_{t+1}^e = B_{t+1} = Q_t K_{t+1} - N_{t+1} \quad (\text{B.1.18})$$

The consumption Euler Equation (B.1.2) is replaced by Equation (E.5) with marginal utility of consumption  $\varrho_t = 1/C_t$

$$\frac{1}{C_t} = (1 - f_t) \beta \mathbb{E}_t \frac{R_{t+1}}{C_{t+1}} + f_t \left( \mu_t + \frac{1}{C_t} \right) \quad (\text{B.1.19})$$

Marginal additional utility of entrepreneurial equity over deposits

$$\mu_t + \frac{1}{C_t} = \beta \mathbb{E}_t \left\{ \frac{R_{t+1}^N}{C_{t+1}} + \gamma \mu_{t+1} R_{t+1} \right\} \quad (\text{B.1.20})$$

Probability that a potential entrepreneur will find funding

$$q_t = s \left( \frac{v_t}{D_{t+1}} \right)^{-\eta} \quad (\text{B.1.21})$$

Euler condition for project pitches with  $\Lambda_{t,t+1} = \varrho_{t+1}/\varrho_t$

$$\frac{\kappa}{q_t} = \beta \mathbb{E}_t \Lambda_{t,t+1} \left\{ \frac{K}{N} R_{t+1}^k - \frac{B}{N} R_{t+1} - R_{t+1}^N + \gamma \frac{\kappa}{q_{t+1}} \right\} \quad (\text{B.1.22})$$

Dividend payments

$$R_t^N = R_t + \lambda \left[ \frac{K}{N} (R_t^k - R_t) + \kappa \frac{f_t}{q_t} \right] \quad (\text{B.1.23})$$

Market clearing, Equation (B.1.1) is modified to

$$Y_t = C_t + I_t + G_t + \mu \int_0^{\bar{\omega}_t} \omega dF(\omega) R_t^k Q_{t-1} K_t + \kappa v_t \quad (\text{B.1.24})$$

## B.2 Log-Linearized: Original BGG

Resource constraint

$$y_t = \frac{C}{Y} c_t + \frac{I}{Y} i_t + \frac{G}{Y} g_t + \frac{C^e}{Y} c_t^e + \dots + \phi_t^y \quad (\text{B.2.1})$$

Consumption Euler relation

$$c_t = -r_{t+1} + \mathbb{E}_t c_{t+1} \quad (\text{B.2.2})$$

Entrepreneurial consumption

$$c_t^e = n_{t+1} + \dots + \phi_t^{c^e} \quad (\text{B.2.3})$$

Supply of investment finance [BGG (4.5)]

$$\mathbb{E}_t r_{t+1}^k - r_{t+1} = \nu [n_{t+1} - (q_t + k_{t+1})] \quad (\text{B.2.4})$$

Expected gross return to capital [BGG (4.4)]

$$r_{t+1}^k = (1 - \epsilon)(y_{t+1} - k_{t+1} - x_{t+1}) + \epsilon q_{t+1} - q_t \quad (\text{B.2.5})$$

Price of capital [BGG (4.3)]

$$q_t = \varphi(i_t - k_t) \quad (\text{B.2.6})$$

Production function [BGG (4.1)]

$$y_t = a_t + \alpha k_t + (1 - \alpha) \Omega h_t \quad (\text{B.2.7})$$

Labor market equilibrium [BGG (4.11) and BGG Appendix (B.4)]

$$y_t - h_t - x_t - c_t = \eta^{-1} h_t \quad (\text{B.2.8})$$

Phillips curve

$$\pi_t = E_{t-1} \{ \kappa(-x_t) + \beta \pi_{t+1} \} \quad (\text{B.2.9})$$

Evolution of capital [BGG (4.2)]

$$k_{t+1} = \delta i_t + (1 - \delta) k_t \quad (\text{B.2.10})$$

Evolution of net worth [BGG (4.13)]

$$n_{t+1} = \frac{\gamma RK}{N} (r_t^k - r_t) + r_t + n_t + \dots + \phi_t^n \quad (\text{B.2.11})$$

### B.2.1 Log-Linearized: Firm entry extension

Equation (B.2.11) becomes

$$n_{t+1} = \frac{\gamma RK}{N} (r_t^k - r_t) + r_t + n_t + \frac{f_{SS} D_{SS}}{N} (\hat{f}_t + d_{t+1}) \dots + \phi_t^n \quad (\text{B.2.12})$$

Probability that a household will find an investment

$$\hat{f}_t = (1 - \eta)(\hat{v}_t - \hat{D}_t) \quad (\text{B.2.13})$$

Effective deposits that have not been invested in equity

$$\hat{D}_{t+1}^e = \frac{f_{SS}}{1 - f_{SS}} \hat{f}_t + \hat{D}_{t+1} \quad (\text{B.2.14})$$

Available deposits at intermediaries, Equation (B.1.14) , becomes

$$\hat{D}_{t+1}^e = \frac{K}{D_{SS}^e} (q_t + k_{t+1}) - \frac{N}{D_{SS}^e} n_{t+1} \quad (\text{B.2.15})$$

The consumption Euler Equation (B.2.2) is replaced by (with  $\hat{q}_t = -c_t$ )

$$\hat{q}_t = \beta R[(1 - f_{SS})(r_{t+1} + \hat{q}_{t+1}) - f_{SS} \hat{f}_t] f_{SS} (\hat{q}_t + \hat{f}_t) + f_{SS} \frac{\mu_{SS}}{\varrho_{SS}} (\hat{\mu}_t + \hat{f}_t) \quad (\text{B.2.16})$$

Marginal additional utility of entrepreneurial equity over deposits

$$\hat{\varrho}_t + \frac{\mu_{SS}}{\varrho_{SS}} = \beta R_{SS}^N (r_{t+1}^N + \hat{\varrho}_{t+1}) + \gamma R \frac{\mu_{SS}}{\varrho_{SS}} (\hat{\mu}_{t+1} + r_{t+1}) \quad (\text{B.2.17})$$

Probability that a potential entrepreneur will find funding

$$\hat{q}_t = \eta(\hat{D}_{t+1} - \hat{v}_t) \quad (\text{B.2.18})$$

Euler condition for project pitches

$$-\hat{q}_t = c_t - c_{t+1} + \frac{1}{*} \left[ \frac{K}{N} R^k r_{t+1}^k - \frac{B}{N} R r_{t+1} - R^N r_{t+1}^N - \gamma \frac{\kappa}{q_{SS}} \hat{q}_{t+1} \right] \quad (\text{B.2.19})$$

Dividend payments

$$R^N r_t^N = R r_t + \lambda \left[ \frac{K}{N} (R^k r_t^k - R r_t) - \gamma \frac{f_{SS}}{q_{SS}} (\hat{f}_t - \hat{q}_t) \right] \quad (\text{B.2.20})$$

Market clearing, Equation (B.2.1) is modified to

$$y_t = \frac{C}{Y} c_t + \frac{I}{Y} i_t + \frac{G}{Y} g_t + \frac{C^e}{Y} c_t^e + \frac{v_{SS}}{Y} \hat{v}_t + \dots + \phi_t^y \quad (\text{B.2.21})$$

## B.3 Steady State: BGG

Resource constraint

$$Y = C + I + G + C^e + \mu \int_0^{\bar{\omega}_t} \omega dF(\omega) R^k K \quad (\text{B.3.1})$$

Consumption Euler relation

$$R = 1/\beta \quad (\text{B.3.2})$$

Entrepreneurial consumption

$$C^e = (1 - \gamma)N \quad (\text{B.3.3})$$

Supply of investment finance [BGG (4.5)]

$$R^k = s \left( \frac{N}{K} \right) R \quad (\text{B.3.4})$$



Expected gross return to capital [BGG (4.4)]

$$R^k = \left\{ \frac{1}{X} \frac{\alpha Y}{K} + (1 - \delta) \right\} \quad (\text{B.3.5})$$

Price of capital [BGG (4.3)]

$$1 = Q = \left[ \Phi' \left( \frac{I}{K} \right) \right]^{-1} \quad (\text{B.3.6})$$

Production function [BGG (4.1)]

$$Y = K^\alpha L^{1-\alpha} \quad (\text{B.3.7})$$

Labor market equilibrium [BGG (4.11) and BGG Appendix (B.4)]

$$(1 - \alpha) \Omega \frac{Y}{H} \frac{1}{C} = X \xi \frac{1}{1 - H} \quad (\text{B.3.8})$$

Phillips curve

$$\pi_t = E_{t-1} \{ \kappa(-x_t) + \beta \pi_{t+1} \} \quad (\text{B.3.9})$$

Evolution of capital [BGG (4.2)]

$$K = \Phi \left( \frac{I}{K} \right) K + (1 - \delta) K \quad (\text{B.3.10})$$

Evolution of net worth [BGG (4.13)]

$$N = \gamma \left[ R^k K - \left( R + \frac{\mu \int_0^{\bar{\omega}_t} \omega dF(\omega) R^k K}{K - N} \right) (K - N) \right] + W^e \quad (\text{B.3.11})$$

Entrepreneurial wage [BGG (4.12)] and  $H^e$  normalized to 1

$$(1 - \alpha)(1 - \Omega)Y = XW^e \quad (\text{B.3.12})$$

Gross nominal interest rate [BGG appendix]

$$1 + i = R \quad (\text{B.3.13})$$

Deposits at intermediaries [BGG appendix and BGG (3.2)]

$$D = B = K - N \tag{B.3.14}$$

## B.4 Data Sources

Parameter	Description	Source	Data Series
$K/N$	1945 - 2014	U.S. Flows of Funds	Z1/Z1/FL102000005.A; Z1/OTHER/FL105080003.A
$R^k - R$	1959 - 2003	St. Louis FRED	DTB6; WPRIME

Table B.1: Data sources and definitions

## APPENDIX TO CHAPTER 4

### C.1 Model Derivation

#### C.1.1 Solution to the Commercial Bank's Problem

Substituting  $D_t$  in Equation (4.7) from Equation (4.6), the ongoing value of a commercial bank Equation (4.8) can be expressed recursively as

$$V_t^{CB} = \nu_t^{CB} Q_t S_t^{CB} + \nu_t^{MCB} M_t^{CB} + \eta_t^{CB} N_t^{CB} \quad (\text{C.1.1})$$

with the marginal benefit from extending loans  $\nu_t^{CB}$  given by

$$\nu_t^{CB} = \mathbb{E}_t\{(1 - \theta_{CB})\beta_{t+1}\Lambda_{t,t+1}(R_{t+1}^K - R_{t+1}) + \beta_{t+1}\Lambda_{t,t+1}\theta_{CB}x_{t+1}^{CB}\nu_{t+1}^{CB}\}, \quad (\text{C.1.2})$$

where  $x_{t+1}^{CB}$  is the gross growth rate of assets  $Q_{t+1}S_{t+1}^{CB}/Q_tS_t^{CB}$ . Similarly, the marginal benefit from extending commercial paper  $\nu_t^{MCB}$  given by

$$\nu_t^{MCB} = \mathbb{E}_t\{(1 - \theta_{CB})\beta_{t+1}\Lambda_{t,t+1}(R_{t+1} - R_{t+1}) + \beta_{t+1}\Lambda_{t,t+1}\theta_{CB}x_{t+1}^{MCB}\nu_{t+1}^{MCB}\}, \quad (\text{C.1.3})$$

where  $x_{t+1}^{MCB}$  is the gross growth rate of commercial paper  $M_{t+1}^{CB}/M_t^{CB}$ . The marginal benefit from extending net worth  $\eta_t^{CB}$  is

$$\eta_t^{CB} = \mathbb{E}_t\{(1 - \theta_{CB})\beta_{t+1}\Lambda_{t,t+1}R_{t+1} + \beta_{t+1}\Lambda_{t,t+1}\theta_{CB}z_{t+1}^{CB}\eta_{t+1}^{CB}\}, \quad (\text{C.1.4})$$

and the gross growth rate of net worth  $z_{t+1}^{CB} = N_{t+1}^{CB}/N_t^{CB}$ .

Together with the incentive constraint in Equation (4.9), the Lagrangian can be written

$$\begin{aligned} \mathbb{L} &= V_t^{CB} + \mu_t^{CB}[V_t^{CB} - \lambda^{CB}(Q_t S_t^{CB} + [1 - \lambda^{ABS}]M_t^{CB})] \\ &= (1 + \mu_t^{CB})(\nu_t^{CB} Q_t S_t^{CB} + \nu_t^{MCB} M_t^{CB} + \eta_t^{CB} N_t^{CB}) - \mu_t^{CB} \lambda^{CB}(Q_t S_t^{CB} + [1 - \lambda^{ABS}]M_t^{CB}). \end{aligned}$$

The first order conditions with respect to  $S_t^{CB}$ ,  $M_t^{CB}$  and  $\mu_t^{CB}$  are, respectively,

$$(1 + \mu_t^{CB})\nu_t^{CB} = \mu_t^{CB}\lambda^{CB} \quad (C.1.5)$$

$$(1 + \mu_t^{CB})\nu_t^{MCB} = \mu_t^{CB}\lambda^{CB}[1 - \lambda^{ABS}] \quad (C.1.6)$$

$$Q_t S_t^{CB}(\nu_t^{CB} - \lambda^{CB}) + M_t^{CB}(\nu_t^{MCB} - \lambda^{CB}[1 - \lambda^{ABS}]) + \eta_t^{CB} N_t^{CB} = 0. \quad (C.1.7)$$

Equations (C.1.5) and (C.1.6) result in  $\nu_t^{MCB} = \nu_t^{CB}[1 - \lambda^{ABS}]$ , which can be substituted into Equation (C.1.7) to yield

$$Q_t S_t^{CB} + M_t^{CB}(1 - \lambda^{ABS}) = N_t^{CB} \phi_t^{CB}, \quad (C.1.8)$$

with the endogenous leverage variable given by

$$\phi_t^{CB} = \frac{\eta_t^{CB}}{\lambda^{CB} - \nu_t^{CB}}. \quad (C.1.9)$$

### C.1.2 Solution to the Shadow Bank's Problem

Substituting  $M_t^{CB}$  in Equation (4.20) from Equation (4.18), the ongoing value of a shadow bank Equation (4.19) can be expressed recursively as

$$V_t^{SB} = \nu_t^{SS} Q_t S_t^{SB} - \nu_t^{MF} M_t^{IF} + \eta_t^{SB} N_t^{SB} \quad (C.1.10)$$

with the marginal benefit from extending loans  $\nu_t^{SB}$  given by

$$\nu_t^{SS} = \mathbb{E}_t\{(1 - \theta_{SB})\beta_{t+1}\Lambda_{t,t+1}(R_{t+1}^K - R_{t+1}^{MCB}) + \beta_{t+1}\Lambda_{t,t+1}\theta_{SB}x_{t+1}^{SS}\nu_{t+1}^{SS}\}, \quad (C.1.11)$$

where  $x_{t+1}^{SS}$  is the gross growth rate of assets  $Q_{t+1}S_{t+1}^{SB}/Q_tS_t^{SB}$ . Similarly, the marginal benefit from increasing funding by commercial paper held by investment funds is  $\nu_t^{MF}$  given by

$$\nu_t^{MF} = \mathbb{E}_t\{(1 - \theta_{SB})\beta_{t+1}\Lambda_{t,t+1}(R_{t+1}^{MIF} - R_{t+1}^{MCB}) + \beta_{t+1}\Lambda_{t,t+1}\theta_{SB}x_{t+1}^{MF}\nu_{t+1}^{MF}\}, \quad (C.1.12)$$

where  $x_{t+1}^{MF}$  is the gross growth rate of commercial paper  $M_{t+1}^{IF}/M_t^{IF}$ . The marginal benefit from extending net worth  $\eta_t^{SB}$  is

$$\eta_t^{SB} = \mathbb{E}_t\{(1 - \theta_{SB})\beta_{t+1}\Lambda_{t,t+1}R_{t+1}^{MCB} + \beta_{t+1}\Lambda_{t,t+1}\theta_{SB}z_{t+1}^{SB}\eta_{t+1}^{SB}\}, \quad (C.1.13)$$

and the gross growth rate of net worth  $z_{t+1}^{SB} = N_{t+1}^{SB}/N_t^{SB}$ .

Together with the incentive constraint in Equation (4.21), the Lagrangian can be written

$$\begin{aligned}\mathbb{L} &= V_t^{SB} + \mu_t^{SB}[V_t^{SB} - \psi^{CB}(M_t^{IF} + [1 - \lambda^{ABS}]M_t^{CB})] \\ &= (1 + \mu_t^{SB})(\nu_t^{SS}Q_tS_t^{SB} - \nu_t^{MF}M_t^{SB} + \eta_t^{SB}N_t^{SB}) - \mu_t^{SB}\psi^{CB}(Q_tS_t^{SB}[1 - \lambda^{ABS}] + \lambda^{ABS}M_t^{IF}).\end{aligned}$$

The first order conditions with respect to  $S_t^{SB}$ ,  $M_t^{IF}$  and  $\mu_t^{SB}$  are, respectively,

$$(1 + \mu_t^{SB})\nu_t^{SS} = \mu_t^{SB}\psi^{CB}(1 - \lambda^{ABS}) \quad (\text{C.1.14})$$

$$(1 + \mu_t^{SB})\nu_t^{MF} + \mu_t^{SB}\psi^{CB}\lambda^{ABS} = 0 \quad (\text{C.1.15})$$

$$Q_tS_t^{SB}(\nu_t^{SS} - \psi^{CB}[1 - \lambda^{ABS}]) - M_t^{IF}(\nu_t^{MF} + \psi^{CB}\lambda^{ABS}) + N_t^{SB}(\eta_t^{SB} + \psi^{CB}[1 - \lambda^{ABS}]) = 0. \quad (\text{C.1.16})$$

Equations (C.1.14) and (C.1.15) result in  $\nu_t^{MF} = -\nu_t^{SS} \frac{\lambda^{ABS}}{1 - \lambda^{ABS}}$ , which can be substituted into Equation (C.1.16) to yield

$$Q_tS_t^{SB} = N_t^{SB} \frac{\eta_t^{SB} + \psi^{CB}(1 - \lambda^{ABS})}{\psi^{CB}(1 - \lambda^{ABS}) - \nu_t^{SS}} - M_t^{IF} \frac{\lambda^{ABS}}{1 - \lambda^{ABS}}. \quad (\text{C.1.17})$$

### C.1.3 Interest Rate Bargaining

Households and investment funds share the joint value they derive from having established a match via Nash bargaining according to the household bargaining power  $\zeta^{HH}$ . Interest rates are negotiated that maximize a convex combination of the surpluses,

$$R_t^{IF} = \argmax \quad \zeta^{HH} \ln V_t^{HH} + (1 - \zeta^{HH}) \ln V_t^{IF}.$$

The household value  $V_t^{HH}$  is made up of the value of owning a fund share  $V_t^{HH,e}$  versus saving deposits at a commercial bank  $V_t^{HH,u}$ :

$$\begin{aligned}V_t^{HH,e} &= R_t^{IF} + \mathbb{E}_t \beta_{t+1} \Lambda_{t,t+1} [\theta_{IF} V_{t+1}^{HH,e} + (1 - \theta_{IF}) V_{t+1}^{HH,u}] \\ V_t^{HH,u} &= R_t + \mathbb{E}_t \beta_{t+1} \Lambda_{t,t+1} [f_t V_{t+1}^{HH,e} + (1 - f_t) V_{t+1}^{HH,u}].\end{aligned}$$

Together they make up the household value

$$V_t^{HH} = R_t^{IF} - R_t + \mathbb{E}_t \beta_{t+1} \Lambda_{t,t+1} (\theta_{IF} - f_t) V_{t+1}^{HH}. \quad (\text{C.1.18})$$

From the first-order condition for interest rate bargaining I know that

$$\frac{\zeta^{HH}}{V_t^{HH}} = \frac{(1 - \zeta^{HH})}{V_t^{IF}}.$$

Solving this forward one period and substituting into Equation (C.1.18), as well as inserting  $\mathbb{E}_t \beta_{t+1} \Lambda_{t,t+1} V_{t+1}^{IF} = \kappa/q_t$  from Equation (4.14), I get for the return investment funds have to pay on their shares

$$R_t^{IF} = R_t + \zeta^{HH} \left\{ \psi^{IF} R_t^{MIF} + (1 - \psi^{IF}) R_t^K - R_t + \kappa \frac{f_t}{q_t} \right\}.$$

Note that investment funds can get away with paying only the risk-free deposit rate in case that they have all the bargaining power. The interest rate on investment shares rises with the bargaining power of households, guaranteeing at least the risk-free rate.

## C.2 Robustness of matching elasticity $\xi$

The parameter for matching elasticity  $\xi$  is important for the dynamics of the matching friction. The value is determined by the Bayesian estimation as 0.74 with relatively narrow posterior density intervals. However, there is no a priori reason why the value could not be lower. In order to test whether the results depend on the value of the matching elasticity, Figure C.1 shows the response of the economy to the same monetary tightening as in Section 4.4.2 for the different configurations of the financial sector but a matching elasticity of  $\xi = 0.2$ . In this case, household savings play a larger part in establishing new matches.

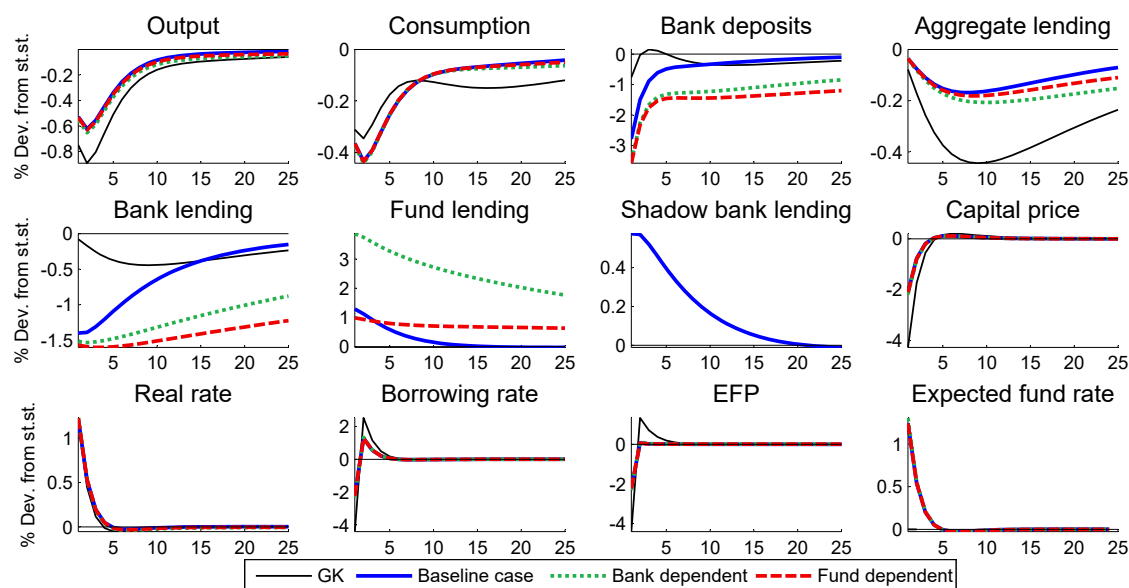


Figure C.1: IRFs to a monetary tightening of 100bp and the matching elasticity  $\xi = .2$ .

The baseline scenario (blue, solid line) is almost unchanged, because investment funds only make up 25% of the credit economy. However, in the bank dependent scenario (green, dotted line), investment funds increase their intermediation by more than with a lower elasticity. This is so because households can more quickly substitute out of deposits and into higher yielding assets. In the fund dependent case, investment fund lending increases more persistently than with a higher elasticity.

In order to study the ZLB case, taking the differences of the responses to a demand shock for constrained and unconstrained monetary policy as in Section 4.5.3 leads to the reactions in Figure C.2. The baseline case is not changed much, and the bank dependent case is qualitatively similar to a higher elasticity. How-

ever, the fund dependent case without shadow banks now shows a reaction that is as favorable as the baseline case with shadow banks.

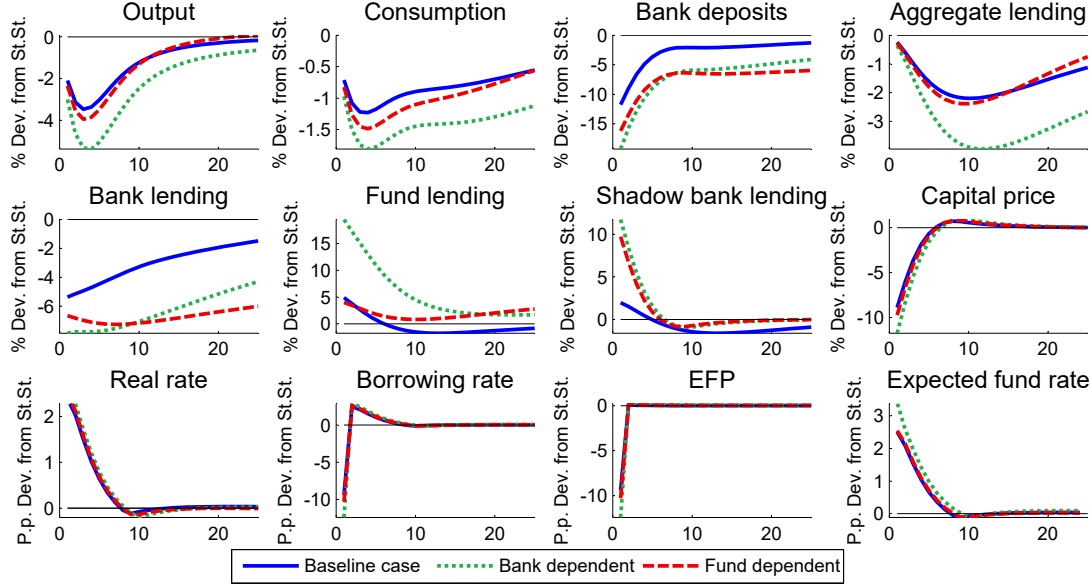


Figure C.2: Difference of IRFs to demand shocks under the ZLB and unconstrained monetary policy. Matching elasticity  $\xi = .2$ .

The robustness analysis shows that the results in the main body of the text can be taken as a lower bound for the reaction of the fund dependent case, while there is not a lot of variation in the baseline and bank dependent cases. The Bayesian estimation provides a narrow standard deviation for the posterior of the matching elasticity. However a quantitative study (e.g., in the case of a welfare analysis) would benefit from further evidence for the exact matching parameter, as the results may change.



## C.3 Empirical Resources

### C.3.1 Data Sources

Variables	Description	Source
Aggregate Output $Y_t$	Real Gross Domestic Product, USD, not s.a.	Stock and Watson (2012)
Consumption $C_t$	Real Personal Consumption Expenditures: Services and Nondurable Goods, USD, not s.a.	Stock and Watson (2012)
Physical Capital $K_t$	Real Private Fixed Investment, USD, not s.a.	Stock and Watson (2012)
M2 Money Supply	M2SL, USD, not s.a.	Stock and Watson (2012)
Total Reserves	TOTRES, USD, not s.a.	Stock and Watson (2012)
Non-borrowed Reserves	NBRES, USD, not s.a.	Stock and Watson (2012)
Inflation $\pi_t$	Consumer Price Index For All Urban Consumers: All Items	Stock and Watson (2012)
Index of sensitive materials prices		Stock and Watson (2012)
Federal Funds Rate $i_t$	Effective Federal Funds Rate	Stock and Watson (2012)
Commercial Bank Loans $S_t^{CB}$	Fixed income credit to the real sector of U.S.-chartered depository institutions and credit unions, USD, not s.a.	Financial accounts of the United States
Investment Fund Loans $S_t^{IF}$	Fixed income credit to the real sector of Money market funds, Mutual Funds, USD, not s.a.	Financial accounts of the United States
Shadow bank Loans $S_t^{SB}$	Fixed income credit to the real sector of ABS Issuers, Finance Companies, Funding Corporations, Security Brokers and Dealers, USD, not s.a.	Financial accounts of the United States

Table C.1: Data sources and definitions. *Note: Fixed income credit to the real sector are loans, bonds, consumer credit and commercial paper.*

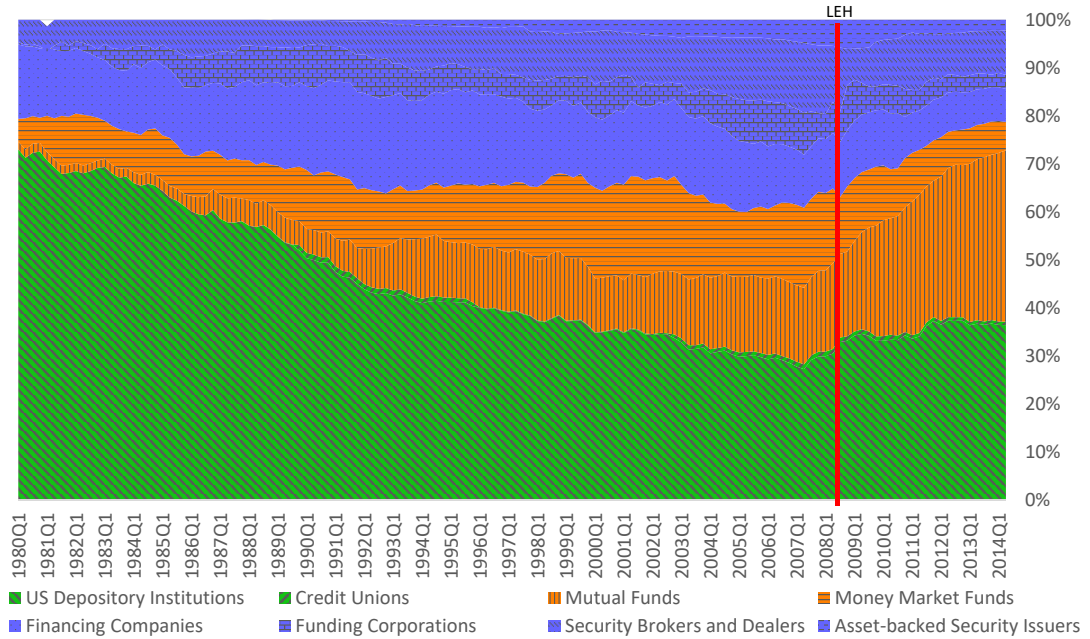


Figure C.3: Timeline of credit intermediation share by the various components of the US financial system, 1980 to 2014. *Note: The red line titled 'LEH' indicates September 15, 2008. Source: Financial accounts of the United States.*

## C.3.2 Full Bayesian VAR

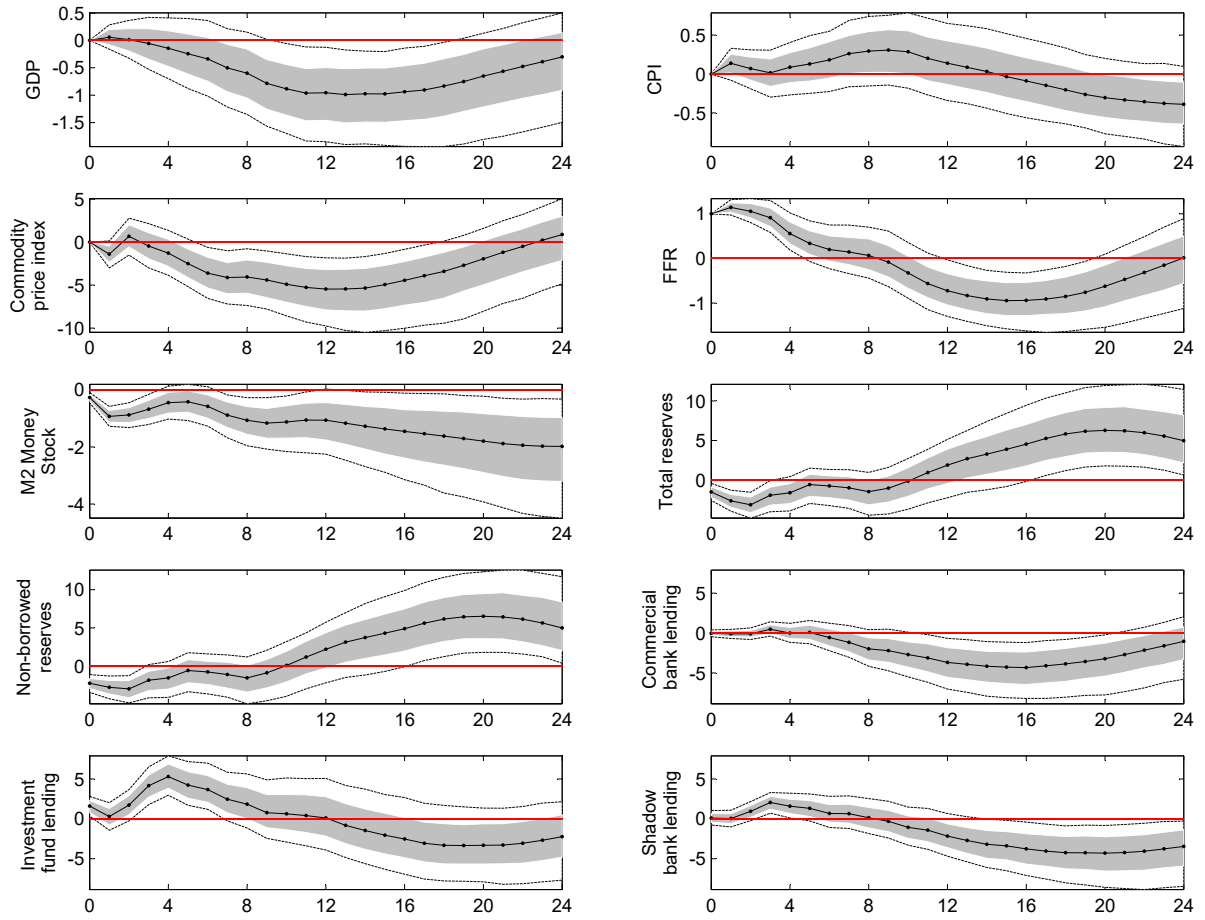


Figure C.4: Response of all variables to a contractionary monetary policy shock. *Note: Empirical impulse responses of all variables to an unanticipated 100 basis point increase in the effective federal funds rate. The horizontal axis reports quarters since the shock. The vertical axis reports percentage deviations from the unshocked path. Shaded regions are 32nd-68th and 10th-90th percentiles of 1000 draws. Source: Mazelis (2016).*

### C.3.3 Bayesian Estimation

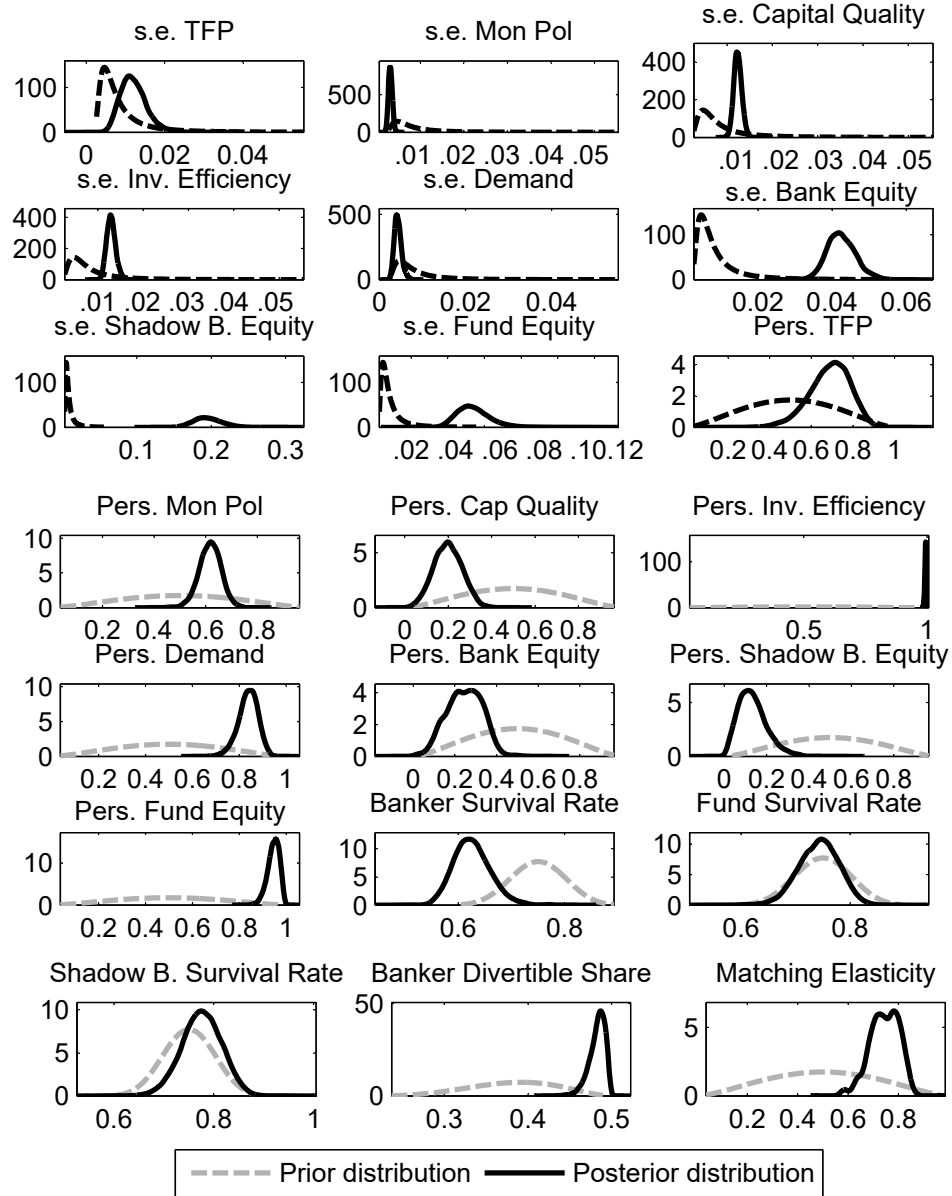


Figure C.5: Posteriors for the standard deviations and persistence of shock processes, and structural parameters. *Note: Bayesian estimation with data from 1984:I to 2006:IV. Posteriors are based on 2 chains of 100,000 draws each. I drop the first 50,000 values of each chain.*

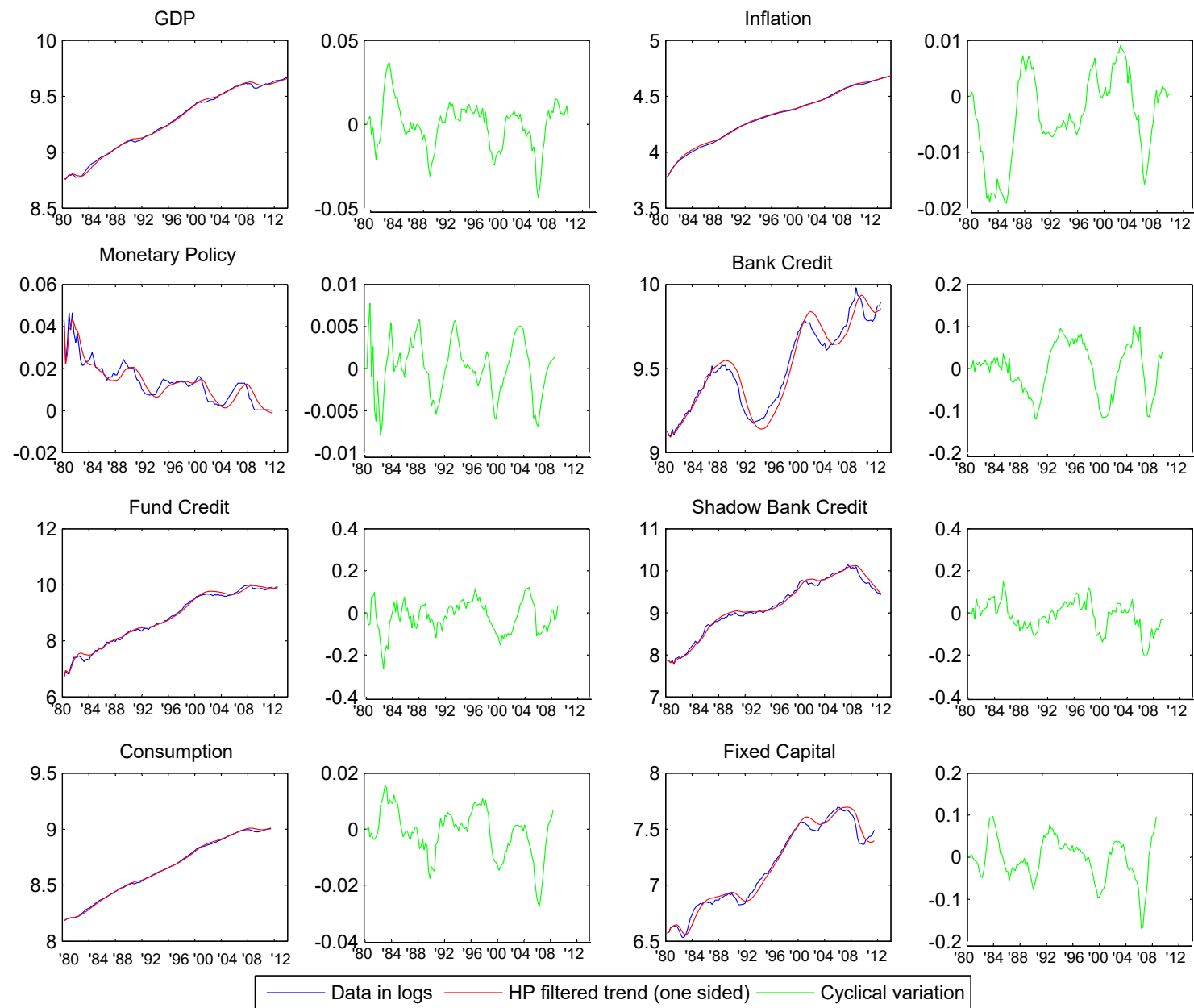


Figure C.6: Data: For each variable, the left panel shows unfiltered data (blue) and the trend component (blue), which is calculated via the one-sided HP filter. The right panel shows the cyclical component (green). *Note: Vertical axes are percentage points divided by 100 for cyclical variations and in logs for raw data and trend components.*

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## SELBSTÄNDIGKEITSERKLÄRUNG

Ich bezeuge durch meine Unterschrift, dass meine Angaben über die bei der Abfassung meiner Dissertation benutzten Hilfsmittel, über die mir zuteil gewordene Hilfe sowie über frühere Begutachtungen meiner Dissertation in jeder Hinsicht der Wahrheit entsprechen.

Falk Mazelis